G. S. SCOTLAND

Memoir 82

LOCH CLAIR, COULIN FOREST. Serpentine Moraine in foreground.

82

MEMOIRS OF THE GEOLOGICAL SURVEY.
SCOTLAND.

THE GEOLOGY

OF

CENTRAL ROSS-SHIRE.

(EXPLANATION OF SHEET 82.)

BY

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WITH

PETROLOGICAL NOTES

BY

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PREFACE.

THE district described in this Memoir comprises the western portion of Central Ross-shire, and is for the most part an uninhabited, mountainous country drained by the rivers Carron, Bran, Meig, Orrin and Farrar. The only villages are Kinlochewe and Lochcarron.

That portion of the Sheet which lies to the west of the Moine thrust-plane was mapped in 1889–1895, and has been fully described in the Memoir on "The Geological Structure of the North-West Highlands of Scotland," published in 1907. In this region the northern face of Beinn Eighe, and a part of Glas Bheinn, north of Loch Carron were mapped by Dr. Peach, the Coulin and Achnashellach Forests from Kinlochewe to the River Lair by Dr. Horne, and the ground between the northern side of Glen Torridon and Strathcarron by Mr. Hinxman. A small area of Torridonian rocks in the extreme north-west corner of the map was examined by Mr. Clough.

The eastern and larger portion of the Sheet was surveyed at a considerably later date. Dr. Peach mapped a strip of ground across the centre of the Sheet from Attadale along the south side of the Carron Valley and Strath Bran to Sgùrr a' Ghlas Leathaid. To Dr. Horne was allotted the area between Kinlochewe and the Highland Railway south of Achnasheen. Mr. Hinxman surveyed the eastern portion of the map between Sgùrr a' Mhuilinn, Scardroy, and the Orrin-Farrar watershed, together with the northern slopes of Glen Cannich, the intervening ground, on either side of the Farrar, being assigned to Mr. Anderson. Mr. Hinxman also mapped smaller areas in the neighbourhood of Attadale and Achnasheen. To Dr. Crampton was given the south-western part of the Sheet, including the Monar and Patt Forests, and to Mr. Carruthers the ground between Loch Monar and Gleann Fhiodhaig. A small area on the north side of Strath Bran was examined by Mr. Greenly.

Dr. Peach acted as District Geologist till his retirement in 1905, Mr. Hinxman subsequently superintended the mapping, and has edited the Memoir. The Index has been drawn up by Mr. Dinham, the Bibliography by Mr. Tait. The Plates are from photographs taken by Mr. R. Lunn. Plate IV. is reproduced from a drawing made from a negative kindly lent to the Survey by the Rev. A. E. Robertson.

J. J. H. TEALL,
Director.

Geological Survey Office,
28 Jermyn Street, London.
29th May 1912.

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GEOLOGY OF CENTRAL ROSS-SHIRE.

CHAPTER I.

AREA AND PHYSICAL FEATURES.

THE land area included in Sheet 82 is approximately 429½ square miles in extent, about 2½ square miles of salt water at the head of Loch Carron entering within the limits of the map. The country represented extends from Kinlochewe and Loch Achanalt in the north to Loch Carron and the northern slopes of Glen Cannich which form the south-eastern margin of the map.

With the exception of a small part of Inverness-shire in the south-east corner, on either side of Glen Strath Farrar, the whole of the area falls within the County of Ross.

The district presents a typical example of a Highland area in which cultivation and population are reduced to a minimum and confined to the sea-board and a few spots along the larger river-valleys. Otherwise the ground is almost entirely given up to deer forest and grouse moor, with small and decreasing areas of sheep grazing at Kinlochewe, Lochcarron and Scardroy.

It is probable that almost the whole of the map falls within the area in which the mean annual rainfall exceeds 60 inches. The average annual precipitation for ten years at Strome Ferry, just outside the south-western margin of the Sheet, is 60·85 in.; at Dalbreac in Strath Conon, close to the eastern limit, 49·76 in.; while at Loch Torridon and Glen Carron, situated in narrow glens among lofty mountains, the average fall is respectively 88·58 and 90·23 in., and at the latter station has reached as high a figure as 109 in. for the year.

The tract of country under consideration may be described as a more or less denuded, high mountain plateau, falling towards the north-east, and reaching its greatest elevation along a line drawn from Beinn Eighe in the north-west corner of the map to An Riabhachan and Sgùrr na Lapaich on the southern margin.

The most obvious features in the surface relief are the three through-valleys which cross the region in a nearly parallel E.N.E.-W.S.W. direction.

The central valley, by which the Highland Railway has been brought through this wild and otherwise almost inaccessible country,

extends obliquely across the centre of the map and crosses the main watershed at a point only 645 ft. above sea-level. On one side of the divide the water flows east to the Conon and the Moray Firth; on the other, through Strath Carron to Loch Carron and the Atlantic. The northern valley runs from Kinlochewe to Loch Torridon, crossing the watershed at a level of 343 ft., and carrying the only driving road to the country round Loch Torridon.

The third depression forms the valley of the river Farrar, the basin of Loch Monar and the flat valley of An Gead Loch; and is continued westwards across the watershed, where the height of the col is 865 ft., and down the valley of the Ling.

The least dissected portion of the plateau is found on the south-east side of the central valley, and surrounds the deep basin of Loch Monar, which lies 663 ft. above sea-level. The principal summits of this great mountain-mass are, on the south side of the basin, Sgùrr na Lapaich, 3773 ft. and An Riabhachan, 3696 ft.; on the north and west, Lurg Mhòr, 3234; Sgùrr Choinnich, 3260; Sgùrr a' Chaorachain, 3452; Bidean an Eòin Deirg, 3430; Maoile Lunndaidh, 3294; and Moruisg, 3026 ft.

Between Glen Carron and Glen Torridon another mass of high ground, more broken up into ridge and valley than that last described, includes the peaks of the Coulin and Achnashellach forests, most of which reach a height of about 3000 ft.; and on the north side of the Torridon valley rise the isolated mountain-masses of Liathach, 3456 ft., and Beinn Eighe, 3509.

In this north-western region the heads of the opposing glens have been lowered to a level considerably below that of the summit-ridges, and separate the mountains from one another by valleys of great depth. Thus the valley that divides Liathach and Beinn Eighe from the high ground of the Coulin and Achnashellach Forests is, at its highest point, less than 400 ft. above sea-level.

In the last-named district the separation into distinct mountain peaks is less complete. The dominant feature on the west side of Glen Carron is the more or less continuous ridge that extends south-west from Loch Clair to the edge of the map, and presents a steep scarped face to the north-west, while on its eastern side lofty spurs, separated by deep glens and corries, project at right angles to the main range. The lowering of the cols at the heads of the through-valleys is in some measure due to differential glacial erosion during the earlier stages of the glaciation. The subject is referred to later, in Chapter XI.

The Sgùrr a' Mhuilinn massif, three of whose peaks reach a height of over 2750 ft., forms another somewhat isolated high-level area in the north-east corner of the map.

The mountains on the south side of the central valley are mainly composed of the metamorphic rocks of the Moine Series, while comparatively unaltered Torridonian and Cambrian sediments enter into those of the Achnashellach and Torridon forests.

The difference in lithological character of these formations, together with the effect of the greater precipitation on the western side of the watershed, find expression in the contrasting mountain forms characteristic of the two regions above mentioned.

The mountains of the Moine Schist area present, as a rule, and

VALLEY OF THE MEIG, LOOKING NORTH-EAST FROM INVERCHORAN.
A River Valley developed along the Shatter-zone of the Strathconon Fault.

especially where composed of the more siliceous members of that series, broad summit-ridges or plateaux, while smooth and often grassy slopes separate the craggy, rather than precipitous, glens and corries. Where, however, the coarse pelitic gneiss of the Moine Series rises into high mountain ground, and the erosion of the heads of the corries has been carried far back into the summit-ridge, narrow, shattered crests and deep, rock-walled cirques are formed, such as those found on An Riabhachan, Sgùrr na Lapaich, and some of the hills of the West Monar Forest. Mural precipices, splintered knife-edges, spiry cones and long bare scree-slopes, on the other hand, characterise the sandstone and quartzite mountains of the west, while the rapid alternation of the Torridonian and Cambrian rocks along the zone of disturbance in the Coulin and Achnashellach Forests gives rise to an intermingling of the mountain forms proper to each of these formations.

The characteristic scenery of the Lewisian Gneiss is well illustrated in the undulating rocky plateau, broken into abrupt craggy hills and deep lochan-filled hollows, that rises above the southern shore of Loch Carron, and the same type of surface features is even observable in the smaller inliers, as around Scardroy and in Glen Orrin.

Features due to Faulting.—Several of the larger structural features of the region are due, directly or indirectly, to lines of dislocation. The Strathconon fault, described in the sequel, Chapter X., enters the north-eastern margin of the map at the foot of Gleann Méinich, and following a direct south-westerly course, passes out of the Sheet immediately to the west of An Riabhachan. This powerful line of disruption has determined the change in trend from E. to N.E. of the straight cañon-like valley of the Meig below Inverchoran (see Plate II.) and also the further alignment of Gleann Chorainn, the Orrin valley above Loch na Caoidhe, and the glen that falls from the head of the Orrin to Lùb-an-inbhir on Loch Monar. The N.E.-S.W. trend of the loch at that point may also be ascribed to the influence of the fault on the direction of ice erosion. A series of escarpments running south-west from Aultfearn and along the valley of the Allt Riabhachain indicates the further course of the fault south of Loch Monar.

The deep valley of Glen Docherty, through which passes the road to Kinlochewe, and the basin of Loch Beannacharain in the Meig valley, coincide with the eastward extension of the large fault which has determined the northern shore of Loch Maree. The lower portion of Strath Carron, from Lair to the head of Loch Carron, has also probably been defined by a fault-line which, leaving the valley near Kirkton, runs westward through Glen More to Loch Kishorn (Sheet 81).

A straight valley-feature that passes through the Bearneas at the head of Loch an Laoigh in a N.E.-S.W. direction, coincides with a belt of crushed and shattered rock that can be traced along the Eas Bàn into Attadale, and evidently represents a line of fault.

The abnormal features of a valley that has been developed along the line of a powerful crush or dislocation are well exemplified in the abrupt and unsmoothed outlines of the sides of Glen Docherty

and of Gleann Chorainn, and especially in that part of the valley of the Meig which coincides with the Strathconon fault. The graded and waste-filled condition of the valley between the foot of Loch Beannacharain and Gleann Mḗinich is due partly to the great amount of detritus brought down by the Allt Gleann Chorainn and other tributaries that follow or cross the belt of shattered rock, and partly to the fact that the erosion of this section of the valley has been retarded by the stream having to operate in more solid material below the point where it leaves the line of fracture.

In the area of disturbance to the north-west of the central valley, the outcrops of the major thrust-planes often give rise to well-marked features where the Torridonian and Cambrian strata are brought into contact with one another. The outcrop of the Kishorn thrust, in particular, produces a very conspicuous feature in the landscape, especially where the Lewisian rocks rest upon the softer members of the Cambrian series.

Features due to Glaciation.—In a region so mountainous and lying, for the most part, so near the sources of the ice-streams, the influence of glacial action on the surface relief is naturally shown more in the results of erosion than in those of accumulation. The former process is strongly evident in the glaciated surfaces of the Torridonian area in the north-west, and the rock-basins, hanging corries and over-deepened valleys of the central and eastern regions.

The picturesquely wooded gorge, well seen from the railway, through which the river Carron rushes in its course between Loch Sgamhain and Craig, is a good example of a gorge, largely post-glacial, but initiated during the retreat of the ice, and eroded in the bottom of a U-shaped glacial valley. A similar instance is found in the upper part of the Ling, and in portions of the course of the Meig above Loch Beannacharain.

Features caused by glacial aggradation are less prominent, and are confined to occasional stretches of morainic drift on the lower hill-slopes, barriers of glacial or fluvio-glacial material at the mouths of some of the lochs, and lateral and terminal moraines in the valleys, glens and corries.

Present Drainage System.—The main watershed of the country forms a sinuous line from north to south across the centre of the Sheet. It is nowhere distant more than 15 miles from the west coast, and on the summit of Beinn Dronaig is only 7 miles from the salt water of Loch Carron. The ground to the west is drained by the Coulin or Kinlochewe River, the Torridon, the Carron and the Ling. That to the east includes the upper portions of the basins of the Bran, Meig and Orrin—all tributaries of the Conon, while the region farther to the south is drained by the Farrar and the Cannich, both of which form part of the Beauly river-system.

Throughout the district the westward-flowing streams show a tendency to increase their gathering ground at the expense of the drainage areas of those flowing east; and in almost every valley the former are cutting back into the steeper western side of the central ridge at a greater rate than the more graded upper portions of the

eastern stream-courses. Many distinct examples of the capture of the headwaters of one stream by another are found within the Sheet.

Thus the river Carron, eroding eastwards through Glen Carron to the alluvial flat which represents what was at one time the silted-up head of Loch Sgamhain, has beheaded the stream which flows through Loch Gowan into the Bran, robbing it of the waters of Loch Sgamhain and the Allt Coire Crubaidh. Farther down Glen Carron the Allt a' Chonais, flowing in from the south, appears to have stolen the Pollan Buidhe from the Meig basin and perhaps also tapped the sources of the Amhainn Bhearnais, one of the headwaters of the river Ling. So, too, the Torridon River, cutting back to the flat watershed above Lochan Iasgaich, has plainly captured the Allt a' Choire Dhuibh Mhòir, the headwaters of the Kinlochewe River.

The most striking instance of this process is found, however, at the head of the long level valley of An Gead Loch, through which the waters of Loch Calavie flow to Loch Monar. The height of the drift-covered watershed is here 865 ft. and on the western side, only a few feet below, lies the flat marshy valley of the Allt an Loin-fhiodha, which extends westwards to a point a short distance beyond the foot of Loch Cruoshie. Below this point the stream, a tributary of the Ling, is rapidly eroding its steep gorge, and it is evident that the water which drains into Loch Cruoshie as well as that of the Allt na Sean-lùibe have been diverted from the basin of the Farrar into that of the Ling.

The principal rivers of the area, the Bran, the Meig, the Orrin, the Farrar, and the Cannich which crosses the extreme south-east corner of the map—all flow in a direction that is generally transverse or transverse-oblique, though modified in parts by faulting, to the normal strike of the rocks. Their courses can also be described as consequent on the eastward slope of the original plateau on which they were initiated.

The western streams, on the other hand, may be regarded as largely obsequent in character, their higher portions, as already pointed out, having been chiefly developed at the expense of the drainage area on the east side of the watershed.

The river Bran, formed by the junction, at Achnasheen, of the streams flowing through Loch a' Chroisg and Loch Gowan, is the largest of the headwaters of the Conon river-system. It has a course within this map of nearly ten miles, and joins the Meig below Loch Luichart in the next Sheet (83) to the east. Below Dosmuckeran, in Strath Bran, the stream winds through a wide alluvial plain which represents the former extent westwards of a lake, some four miles in length, whose waters have been partly silted-up by the stream at the head and partly drained at the foot by the lowering of the rock barrier below Loch a' Chuilinn. The former continuity of that loch with Loch Achanalt is shown by the alluvial terraces which surround both pieces of water.

The Meig flows eastwards through Gleann Fhiodhaig and Loch Beannacharain to Inverchoran, where its course is diverted to the north-east by the Strathconon fault, as already described. At

Scardroy the valley is crossed by a barrier of Lewisian Gneiss over which the river pours in a fall, while openings in the barrier at higher levels and corresponding terraces indicate the course of the stream at an earlier period of erosion.

The headwaters only of the Orrin fall within the present area, and the greater part of its course passes through a chain of small lochs and partially drained lake-basins.

The largest stream within the Sheet is the Farrar, one of the three principal components of the Beauly river-system.

The Farrar issues from Loch Monar, which is fed by the waters of the Amhainn an t-Sratha Mhòir, the Allt Loch Calavie, and other smaller streams that drain the area of high mountain ground around that loch.

The true outlet of the Farrar from Loch Monar is at the head of the gorge of the Garbh-uisge (Rough Water), the alluvial deposit opposite Monar Lodge representing a portion of the loch which has been filled up with the detritus brought down by the Allt Coire na Faochaige.

The Garbh-uisge gorge, through which the river falls nearly 200 ft. in a distance of less than a mile, is being eroded through the barrier of massive siliceous schists which holds up the waters of Loch Monar. This channel is, in its lower part at least, post-glacial in origin, and the hollow between Loch Bad na h-Achlaise and the Uisge Misgeach indicates the former course of the river.

A waste-filled basin, 1½ miles in length, below Broulin Lodge marks the site of a drained loch above another eroded barrier; and the former extent of the waters of Loch a' Mhuillidh, on the margin of the map, is shown by the high terraces, 20 ft. above the present level of the loch, which extend eastwards to Loch Beanachran in the next Sheet (83).*

Lakes.—The principal lakes within this Sheet are—in the basin of the Bran, Loch an Fhiarlaid, Loch a' Chroisg, Loch Gowan, and Loch Achanalt; Loch Beannacharain on the Meig; Loch na Caoidhe at the head of the Orrin; Loch Calavie, An Gead Loch, Loch Monar and Loch a' Mhuillidh in the Farrar basin On the west side of the watershed are Loch an Laoigh at the head of the Ling; Lochs Sgamhain and Dùghaill on the Carron, and Lochs Coulin and Clair; besides many other smaller tarns and corrie lochans scattered throughout the area.

Nearly the whole of the lochs mentioned above have been sounded by the members of the Scottish Lake Survey, and most of the following facts are recorded by Sir John Murray and Mr. L. Pullar, (*op. cit.* vol. ii.)†

Loch a' Chroisg.—To a considerable extent held up by a barrier of fluvio-glacial deposits, but partially also a rock-basin; the bottom of the lake being 60 ft. below the level of the first appearance of rock in the bed of the river Bran, 2 miles east of Achnasheen.

* For a fuller description of the Conon and Beauly river-systems, see "The Beauly and Conon," L. W. Hinxman, *Scot. Geog. Mag.*, 1907, vol. xxiii. p. 192.

† "Bathymetrical Survey of the Scottish Freshwater Lochs," 6 vols. Edin., 1910.

The bathymetrical contours indicate a simple central basin in which the maximum sounding, 168 ft., was obtained opposite the mouth of the Allt Duchairidh.

Loch Achanalt.—A shallow, reedy piece of water in the process of being rapidly silted up. It communicates by a short stream with Loch a' Chuilinn and was at one time continuous with that loch. The latter, most of which lies outside this map, is a rock-basin.

Loch Gowan.—A long, narrow loch whose waters are probably almost entirely held up by glacial material. A large area at the head of the loch has been filled up, and the cone of alluvium deposited by the burn at Inver nearly divides the lake into two separate basins. The greatest depth, 52 ft., is found in the southern basin.

Loch Calavie.—The source of one of the headwaters of the river Farrar, and, though surrounded by moraines, mainly a rock-basin of simple form, with a maximum depth of 84 ft. found in a central position. Loch Mhuilich is also a rock-basin.

Lower down the course of the stream flowing from Loch Calavie are the *Gead Lochs*, a chain of comparatively shallow lochs, with very uneven bottoms, occupying hollows in the morainic deposits of the later glaciation. The greatest depth found in Loch an Tachdaidh is 62 ft., in An Gead Loch, 30 ft.

Loch Monar.—This, the largest piece of water within the map, has a length of over four miles, with a mean breadth of nearly a third of a mile, and covers an area of 750 acres or over one square mile. The former extension of the head of the loch for more than a mile to the westward is indicated by the wide stretch of flat alluvium along the lower course of the Amhainn an t-Sratha Mhòir. Loch Monar is a true rock-basin, the lip and real outlet of the loch being over a rock floor at the head of the gorge of the Garbh-uisge. The bathymetrical contours show a simple conformation, but all approach nearer to the eastern than the western end of the loch, and the deepest sounding, 260 ft., was obtained in the constricted portion east of Lùb-an-inbhir, 3 miles from the head of the loch. It is significant that the deepest part of the basin lies in the zone of shattered rock between the Strath-conon fault, which crosses the loch at Lùb-an-inbhir, and a parallel fault a mile to the east.

Loch a' Mhuillidh is a small rock-basin of simple form, the greatest depth, 84 ft., occurs to the west of the small island and underneath the lofty crag that rises on the north side of the loch.

Loch na Caoidhe, at the head of Glen Orrin, although surrounded by moraines, probably occupies a rock-basin, the river at its outlet having cut down through the moraine to the underlying rock-lip. Am Fiar-loch and the smaller pools below are the remains of a large loch which occupied the waste-filled basin further down the stream. References to Loch Dùghaill and Loch Sgamhain, and to many other smaller pieces of water, will be found in the account of the glacial history of the country (Chapter XI.). L. W. H.

The heads of the fiords—Loch Torridon and Loch Carron—which enter the western margin of the map, are obviously the seaward

extensions of drowned valleys, pre-glacial in origin, and formed when the land stood at a higher level than at the present time. Subsequent glacial erosion produced over-deepening of the valleys, and excavated a succession of rock-basins—now all beneath sea-level—in their floor; but they were in all probability partly eroded below the present sea-level before the glaciation of the country.

The further extension landward of the waters of these sea-lochs, both during the later stages of the glaciation and after the disappearance of the ice from the lower part of the valleys, is manifest from the distribution of the moraines, fluvio-glacial gravels, raised beaches and river alluvia. Loch Torridon must have extended for some little distance both up the main valley of the Torridon River and of its tributary, Gleann Thràil, while the Carron fiord probably ran inland beyond Loch Dùghaill as far as Craig, to the foot of the present river gorges. B. N. P.

The area under description represents an almost uninhabited region of deer forest and grouse moor, in which the population is chiefly confined to the village of Lochcarron and the crofting hamlets in Strath Carron, together with a few widely scattered lodges, keepers' and shepherds' houses in the larger glens.

Much of the ground formerly under sheep has lately been afforested, but a limited grazing area still remains at Scardroy in the Meig valley, in Strath Bran, and around the head of Loch Carron. Agriculture is carried on in isolated patches along the flood-plains of the principal river-valleys, and on the hill-slopes above Loch Carron.

Timber.—Conifers have lately been planted to a limited extent on the northern shore of Loch a' Chroisg, in Strath Bran, and in the Meig valley; and, together with hardwood trees of several species, flourish well in sheltered situations at Coulin, Achnashellach and Loch Carron.

Natural birchwoods clothe the lower slopes on the southern sides of Glen Strath Farrar and Glen Cannich; and, mingled with ancient pine trees of picturesque form, add to the wild beauty of Glen Carron and the Achnashellach Forest.

Considerable areas of ground in the more sheltered parts of the valleys, and especially in Glen Strath Farrar, might profitably be planted, the loose morainic drift with which so much of the lower slopes is covered affording a soil particularly well adapted to the growth of pine and larch. L. W. H.

CHAPTER II.

FORMATIONS AND ROCK GROUPS AND THEIR GENERAL DISTRIBUTION IN THE AREA.

THE following table shows the geological formations represented in the area, together with the symbols used upon the map:—

Pleistocene and Recent.	Landslips.		
	Peat.		
	Cones and Deltas.		
	River terraces and freshwater alluvia.		
	Raised beaches and marine alluvia.		
	Fluvio-glacial sands and gravels.		
	Morainic deposits.		
	Boulder-clay.		
Cambrian.	Limestone		a
	Serpulite Grit		a
	"Fucoid Beds" (Olenellus zone)		a
	"Pipe Rock"		a
	Basal quartzite		a
Torridonian.	Where affected by post-Cambrian movements		t'
	Undifferentiated		t
	Aultbea Group		t^{III}
	Applecross Group		t^{II}
	Diabaig Group		t^{I}
Moine Series.	Granulitic schists (undifferentiated)		m
	Siliceous schists		x^{m}
	Pelitic gneiss		g^{m}
	Mylonised rocks, in advance of the Moine thrust		μ
Lewisian. East of the Moine Thrust.	Graphitic schist		$g^{1}\mathfrak{A}''$
	Limestone and calc-silicate rocks		$\lambda\mathfrak{A}''$
	Acid and hornblendic gneiss		$\mathfrak{A}''$
	Amphibolite and eclogite		$\mathfrak{D}\mathfrak{A}''$
	Serpentine and peridotite		$\mathfrak{U}\mathfrak{A}''$
In Thrust Masses West of the Moine Thrust.	Acid and hornblendic gneiss		$\mathfrak{A}'$
	Amphibolite		$\mathfrak{D}\mathfrak{A}'$
West of all Post-Cambrian Thrusts.	Acid and hornblendic gneiss		$\mathfrak{A}$
Intrusive Igneous Rocks.	Amphibolite (in Moine Series)		$\mathfrak{D}$
Post-foliation.	Lamprophyre		L
	Granite and pegmatite		G

General Distribution.—The whole of the ground east of the river Carron and of a line drawn from Achnashellach to Kinlochewe, is occupied by crystalline, metamorphic rocks—the siliceous and pelitic schists of the Moine Series—surrounding inliers of complex gneisses of Lewisian type. The latter are most widely developed in the eastern part of the area, where the largest inlier is found in the basin of the Meig, and forms a great part of the mountain Sgùrr a' Ghlas Leathaid. Other smaller masses occur in Glen Orrin, in Glen Strath Farrar, and round the head of Loch Monar. These inliers all lie to the east of the Moine thrust.

Another large mass of Lewisian Gneiss enters the map on either side of Loch Carron, and is continued as a narrow and interrupted belt along the west side of Strath Carron, and northwards through the Coulin Forest to within a short distance of Kinlochewe. This western belt forms part of the thrust masses situated west of the Moine thrust; the portion south of Loch Carron lies to the east of that line of movement.

A portion of a small inlier of unmoved Lewisian rocks appears on the western margin of the map 2½ miles north of the head of Loch Torridon.

The remaining north-western portion of the Sheet is occupied by sedimentary rocks of Cambrian and Torridonian age, these two formations alternating in parallel belts along lines of thrust or natural outcrop; while, in the unmoved area, the Cambrian quartzites cap the highest peaks of Liathach and Beinn Eighe.

L. W. H.

For an account of the work of previous observers in this district the reader is referred to chapter ii. of "The Geological Structure of the North-Western Highlands of Scotland" (*Mem. Geol. Survey*), 1907. In that chapter will be found a *résumé* of the observations made by Nicol, Murchison and Geikie in the area west of the Moine thrust. References to other papers on the geology of the district are given in the Appendix.

NORTH FACE OF SGÒRR RUADH, ACHNASHELLACH FOREST.
Folded Torridon Sandstone (dark) resting upon Thrust-plane, above Cambrian Quartzite (light).

CHAPTER III.

AREA WEST OF THE MOINE THRUST.

i. General Account of the Geological Structure.

In the north-west corner of the map there is a triangular area extending from Beinn Dearg and Ruadh-stac in the north to Srath a' Bhàthaich south of Beinn na h-Eaglaise in which the rocks have not been affected by post-Cambrian thrusts. This undisturbed region is occupied by Torridon Sandstone usually inclined at gentle angles, with patches of quartzite resting unconformably upon it. Part of an inlier of Lewisian Gneiss surrounded by Torridonian strata appears in the valley that separates Beinn Dearg from Liathach to the north of Loch Torridon.

In the belt of complication that intervenes between this undisturbed area to the west and the outcrop of the first great thrust-plane (Kinlochewe and Kishorn) to the east, the type of imbricate structure met with in Assynt and east of Loch Eireboll in advance of the great lines of displacement is rarely represented. In those regions to the north the strata are repeated by reversed faults which lie at an oblique angle to major thrust-planes. Here we find west of the Kinlochewe thrust a constant reduplication of subdivisions of the Cambrian formation, or of Cambrian and Torridonian strata combined, by inverted folds and to a limited extent by reversed faults, all inclined to the east-south-east. This structure may be studied in detail on the slopes of Beinn Eighe, where the Cambrian zones and the underlying Torridon Sandstone have been repeated by this method over a belt several miles in width. Another characteristic feature is the occurrence of strips of Torridon Sandstone and Cambrian quartzite, more or less continuous, which have been reduplicated by folds and reversed faults of varying magnitude. The evidence bearing on this type of structure is remarkable. For example, the outcrop of Cambrian quartzites beneath the Kinlochewe thrust-plane has been traced southwards from Loch Clair to Achnashellach, thence W.S.W. to Loch a' Mhuilinn, north-east of Glas Bheinn, where it joins the belt of quartzites running N.N.E. by An Ruadh-stac to the north-west slope of Sgùrr Dubh. It is clear that the strata within this tract are arranged in a great compound fold, the core of which is occupied by Torridon Sandstone, and that the strips of quartzite are merely infolds on the wrinkled surface, which have been more or less isolated by denudation. The well-marked thrusts, which are easily recognised within this area, are minor displacements of no great extent (see Plate III.).

East and south of this belt of complication appears the Kin-

lochewe or Kishorn thrust, whereby a slice of Lewisian Gneiss and Torridon Sandstone has been driven westwards and made to overlie the piled-up Cambrian strata. Between Kinlochewe at the northern margin of the map and Achnashellach station the displaced materials rarely exceed a mile in width, but within this narrow strip and especially in the Coulin district important evidence is obtained of the deformation of Torridonian strata. Along this portion of the thrust mass we find the incipient development of the great inversion so conspicuous at Strome Ferry, where the overturned floor of Lewisian Gneiss rests on the basal members of the Torridon Sandstone. North from Loch Carron the slice of Lewisian Gneiss attains considerable dimensions and presents conclusive evidence of the modification of the original structures by the post-Cambrian movements.

East of the Kinlochewe displacement lies the Moine thrust, which brings forward a typical development of the crystalline schists of the Moine Series. Of special interest are the narrow strips, near Loch Coulin, of altered sediments in a stage of crystallisation intermediate between the altered Torridonian strata to the west and the Moine schists to the east. The Moine thrust is traceable from Kinlochewe southwards to a point about a mile east from Achnashellach station where it is concealed beneath the alluvium of the Carron valley. From that locality the strike of the tectonic structures trends W. or W.S.W. On the map the outcrop of the Moine thrust is represented as shifted for a distance of about nine miles to near the village of Lochcarron by the fault traversing the valley of the Carron.

J. H.

ii. Lewisian Gneiss.

Unthrust Mass.—The Lewisian Gneiss of the unmoved area to the west of the post-Cambrian thrust-planes is represented in this map solely by a portion of a small inlier which appears among the Torridon sandstones in the valley between Liathach and Beinn Dearg, and rises to a height of 1800 ft. on the slopes of the latter mountain. The rock is interesting as one of the few examples of the muscovite-biotite-gneiss (Group V.) of the Fundamental Complex. The gneiss of this area is thoroughly reconstructed, and shows marked parallel foliation, and is even schistose in places, with a coating of silvery white mica upon the divisional planes. It contains, in addition to the micas, microcline, oligoclase and quartz, and shows traces of cataclastic structure. Associated with the muscovite-biotite-gneiss are biotite-gneisses and bands of garnetiferous amphibolite; some of the latter are markedly schistose. The unconformable junction of the gneiss with the Torridonian is well seen at the highest part of the inlier, where, in the beds of the mountain torrents, the sandstone is seen resting upon the eroded vertical foliation planes of the gneiss.* L. W. H.

Thrust Masses.—The hill of Glas Bheinn and the eastern slopes of Tòrr na h-Iolaire, on the west side of Loch Carron, are formed of a portion of the great mass of thrust gneiss brought forward on the Kishorn thrust-plane. The thickness of gneiss actually seen on the

* See also "The Geological Structure of the N.W. Highlands" (*Mem. Geol Survey*), 1907, pp. 70, 255.

former hill is at least 1700 feet. The outcrop of the thrust-plane on which it rests is well seen along the principal western tributary to the head of the Tullich Burn, and at several places at the foot of the great cliff on the north-west side of the hill. The chief characteristic of this rock, which was originally a hornblendic and micaceous gneiss, is the intense cataclastic action to which it has been subjected. The evidence of this deformation is strongly apparent in the first few feet above the thrust-plane, where the rock is completely drawn out into platy mylonite, independently of the original nature of the gneiss. Higher up in the mass the effect of cataclastic action decreases and the original nature of the gneiss becomes everywhere apparent. It presents knots of early basic material isolated in a more acid, hornblendic or micaceous rock, with masses of hornblendic epidiorite and hornblende-schist later than this Fundamental Complex. All are alike cut by red pegmatites of quartz and felspar, with few or no ferromagnesian constituents.

Along certain planes of movement which dip south-east in a direction parallel to the underlying Kishorn thrust-plane, the rocks are drawn out into mylonites similar to those near that plane. Bands of less crushed material intervene between these lines of movement, but towards the southern edge of the mass the mylonised portions become so numerous that the whole of the rock has been converted into platy mylonite. The best exposures of these mylonites are found in the Amhainn Bhuachaig at Tullich and in the tributary streams to the west. Their relations to the Moine thrust-plane along this line are unfortunately obscured by the powerful normal fault (Glen More fault) which throws down that thrust-plane and brings the overlying Moine schists into direct contact with the mylonites. The outcrop of the Moine thrust-plane is, however, exposed in a tributary of the stream which falls into the sea at Lochcarron village, and here the Lewisian Gneiss is mylonised to a greater degree even than at Tullich. The rolling out is seen to decrease rapidly westwards along this stream, and within a few hundred yards the original structures of the gneiss can again be recognised.

From these facts it would appear that the mylonisation of the gneiss is probably due to the passage over it of the great mass of rock brought forward by the Moine thrust-plane.

The intermittent bands of mylonised rock further within the mass are produced by the dynamical force being transmitted through the more stable portions to successive lines of weakness.

The deformation in these mylonites, although for the most part destructive, is not wholly so, granulitisation of the quartz and felspar having taken place to a considerable extent, accompanied by the setting up of small individuals of secondary mica. In some of these crushed rocks the quartzo-felspathic constituents seem to have yielded more readily to deformation than the hornblende, pellets of this mineral up to ¼ inch in diameter, and representing original crystals, being found set in a matrix of the other components of the rock.

Particular attention should be drawn to the fact that the Lewisian Gneiss which underlies the Kishorn thrust-plane, and is seen along the path leading from Tullich through the pass to Shieldaig, is of a coarse pegmatitic type, and entirely different in character to that of the overlying mass.

Large masses of this coarse acid gneiss occur in the basal conglomerate of the Torridonian, which there lies in inverted order beneath the Lewisian rocks.

The double unconformity of the Cambrian quartzites and Torridonian sandstones upon the gneiss at this horizon shows also that the Torridonian rocks involved in the mass below the Kishorn thrust-plane are high up in the series. Above that thrust-plane we find intervening between the Lewisian Gneiss and the Cambrian quartzite in the Kishorn area, a short distance to the south-west of the present map, a mass of Torridonian rocks mostly belonging to the lowest or Diabaig group, which in Sleat reaches a thickness of at least six thousand feet.

It is thus evident that the difference in the material overlying the Kishorn thrust-plane from that which underlies it is due to the former having been derived from an area considerably further to the east than the latter. B. N. P.

The mass of gneiss that covers the summit and south-eastern slopes of Tòrr na h-Iolaire is comparatively thin, and except in a few places on the top of the hill where the mass is thickest and the original structures have not been entirely obliterated, the rock is in the condition of a green flaggy mylonite. Bands of thoroughly foliated hornblende rock are here and there still recognisable with a few later pegmatite veins.

Small outliers of the same mass are found further up the Carron valley, between Coulags and Balnacra, and above the foot of Loch Dùghaill. The cake that covers the hill-slopes is here very thin and the whole of the rock is completely mylonised. The outcrop of the Kishorn thrust-plane upon which all these masses are resting forms a conspicuous feature that can be traced almost continuously around each individual area. The thrust-plane is for the most part riding upon a piled-up mass of Cambrian Fucoid Beds and Serpulite Grit, repeated by numerous minor thrusts, but in a few places has overlapped on to the underlying quartzite. The small outlier to the north of Balnacra is bounded on its southern side by a normal fault. A stream flowing along this fault-line has eroded a deep gully, in which the pipe-rock is seen in contact alternately with the Fucoid Beds and with the overlying mylonitic gneiss, the whole of the rocks being much crushed and stained with hæmatite.

These Lewisian masses are all cut off on the south by the Glen More fault, which passes down Strath Carron. Its course between Tullich and Loch Dùghaill is concealed beneath superficial deposits. L. W. H.

As already indicated, the narrow belt of Lewisian Gneiss that stretches northwards for six miles from Achnashellach station by Loch Coulin to a point not far south from Kinlochewe Hotel has been carried westwards together with a slice of underlying Torridonian strata by the Kinlochewe thrust. Throughout this line of outcrop the original structures have been largely effaced, and new divisional planes have been superinduced parallel with the strike of the Kinlochewe and Moine thrust-planes and inclined to the east-south-east. In places, however, as on the north shore of Loch Coulin

and on the moor about half a mile north from the head of that loch, the old structures have been more or less preserved. The rocks there consist of hornblende-gneiss, biotite-gneiss with hornblende knots and lenticles, and pegmatites. But as a rule the hornblende-gneiss has been sheared and mylonised, the relics of the original banding being traceable by means of the alternation of darker and lighter folia. Veins of pegmatite present a fluxion structure due to movement, characteristic of the stage of deformation in advance of the Moine thrust. The surfaces of the gneiss between Coulin and Kinlochewe are much epidotized and traversed by strings of epidote.

In the sequel (p. 19) special reference will be made to the exposures of Lewisian rocks in the Coulin Forest appearing along isoclinal folds in the basal division of the Torridon Sandstone.

J. H.

iii. Torridonian.

The Torridonian strata occupy almost the whole of the unmoved area on either side of Glen Torridon in the north-west corner of the map, and enter largely into the belt of disturbed ground west of the Moine thrust-plane.

The most important geological features in the undisturbed area are the Fasagh fault and the anticlinal fold, both of which cross the crest of Liathach and intersect on the northern slopes of that mountain. The downthrow of the Fasagh fault (so called from Fasagh on Loch Maree) is to the east, and its throw, calculated by the displacement of the Cambrian strata farther to the north, must exceed 1000 ft. Its course is marked by the deep cleft on the mountain face above the village of Fasag at the head of Loch Torridon, where it brings down the coarse grits of the upper and middle portions of the Applecross group against the hard red quartzose sandstones that lie at the base of the same group.

The axis of the anticline crosses the summit-ridge of the mountain a little to the west of the highest peak, Spidean a' Choire Léith, where the sandstones are flat or nearly so, but dip away on either side to east and west at angles of 7° to 10°. The corresponding dip of the quartzite that caps the central eastern and western peaks shows that this fold is of post-Cambrian age.

The Torridon mountains are chiefly composed of the coarse chocolate and red arkoses and pebbly grits of the Applecross group—false-bedded, and with occasional seams of shale and flagstone.

Strata which may be assigned to the highest or Aultbea group form the summit of Maol Chean-dearg, where they are superimposed upon the quartzite by a major thrust. They consist of fine-grained, false-bedded red sandstones, the false-bedding inclined at a high angle to the true bedding planes, and often much contorted. Several bands of greenish-grey flags and shales, one of which reaches a thickness of 15 ft., are intercalated with the sandstones. Similar sandstones with green shales compose the upper part of Fuar Tholl, a mountain 3½ miles to the east, and the green and red shales that underlie the quartzite capping on Mullach an Rathain, the western peak of Liathach, may possibly belong to the base of the same group.

L. W. H.

The narrow belt of displaced Torridon Sandstone above the Kinlochewe thrust-plane, between Cnoc Daimh in the Coulin Forest and Kinlochewe, includes representatives of the Diabaig and Applecross groups, which appear in inverted order beneath the strip of Lewisian Gneiss already described (p. 14). The members of the Diabaig group, consisting of epidotic grits, black and grey shales, flags, thin-bedded sandstones and grits, appear in the Coulin Forest and are traceable northwards from Loch Coulin along the escarpments east from Loch Clair, and down the Kinlochewe River towards Cromasag. The strata are inclined to the east-south-east at angles varying from 20° to 30°, and in some instances 60°. The point of special interest connected with these beds is the degree of metamorphism which has been superinduced in them by the post-Cambrian movements. The features of the altered strata in the Coulin Forest will be described in the sequel (p. 21) in association with the tectonics of that area. The metamorphism is also well marked in the beds east from Loch Clair and in the Kinlochewe River, especially about a mile south from Cromasag. All the sediments there are more or less schistose. The grits and sandstones present a flaser structure, the larger grains of quartz and felspar appearing as "eyes" in the wavy matrix. The fine-grained bands are platy with striped surfaces resembling those on the divisional planes of the mylonised rocks near the Moine thrust-plane.

The dominant constituents of these rocks are quartz, felspar (chiefly microcline), and white mica associated with a fine-grained matrix. A suite of specimens collected from these altered Diabaig beds east from Loch Clair and the Kinlochewe River up to the overlying mass of Lewisian Gneiss was examined by Dr. Teall. He found that the larger grains of quartz and felspar are frequently elongated in the direction of flow, and that the lenticular grains of felspar have sometimes tail-like endings, consisting of broken fragments of the grain itself mixed with mylonitic material. The matrix is mylonitic, and has evidently been formed from the crushing down of the larger constituents. The sericitic mica is associated with this matrix. These rocks do not show the characteristic granulitic structure of typical Moine schists.

In these schistose Diabaig beds east from the Kinlochewe River and close to the overlying Lewisian Gneiss a segregation vein, composed of quartz, pink felspar with some iron ores, and scales of chlorite was observed. The quartz and felspar show marked cataclastic structures under the microscope, thereby indicating that the movement must have continued after the segregation had taken place.

Though it is clear that the basal beds of the Diabaig group are in contact with the overlying Lewisian Gneiss north from Loch Coulin, yet at certain points the differential movement is so marked that the original unconformable junction has been effaced. At one locality east from the foot of Loch Clair there is a recognisable thrust-plane between the schistose Diabaig beds (Torridonian) and the overlying sheared Lewisian rocks, but the relative displacement must be insignificant.

Beyond the Diabaig beds west from the Kinlochewe River the coarse pebbly grits and sandstones of the Applecross group come to the surface in inverted order and continue westwards till they are

truncated by the Kinlochewe thrust. They are comparatively unaltered except in a few localities where they are schistose and the bedding-planes have been effaced.

North from Achnashellach station there is a small lenticular patch of schistose Torridon grits and sandstones lying between the Kinlochewe thrust-plane and the Lewisian rocks to the east, the horizon of which has not been definitely ascertained, but the strata probably belong to the Applecross group. J. H.

iv. Cambrian.

Unmoved Area.—The former extension westwards of the Cambrian strata is indicated by the outliers of that formation that cap the higher mountain-tops to the west of the first line of thrust. The greater part of the western ridge of Beinn Eighe is covered with the arenaceous members of the series, resting with a gentle unconformity upon the Torridon Sandstone, while at the 3130-ft. cairn, 1½ miles west of the highest point of Sgùrr Bàn, these are in turn covered by a small patch of the Fucoid Beds and overlying Serpulite Grit. A still smaller outlier of basal quartzite rests upon the summit of Sàil Mhòr (3217).

The three peaks of Liathach are also capped with quartzite, the white glistening scree-slopes forming a striking contrast in colour with the deep red sandstone below. The central cone, Spidean a' Choire Léith (3456), carries a small patch of pipe-rock upon its extreme summit; the eastern and western outliers are of basal quartzite alone. The Cambrian strata dip south-east and south-west on either side of the anticlinal axis that crosses the mountain ridge.

A thin cake of gritty basal quartzite rests naturally, along its western boundary, upon the Torridonian Sandstone on the summit of Seana Mheallan. On the east side the quartzite is cut off by the outcrop of the thrust-plane, bringing on once more the Torridonian rocks.

Disturbed Area.—Among the displaced masses to the east of this line of thrust the Cambrian strata, repeated by numerous folds and minor thrusts, appear in long parallel strips and lenticular masses between the intervening belts of Torridon Sandstone. The normal outcrop of the basal quartzite above the Torridonian rocks can be followed from the north-western slopes of Maol Chean-dearg southwards to An Gorm-loch; and again, in the next thrust mass to the east, from Loch Clair to Loch Cadh' an Eididh north of Glas Bheinn. The two zones of the quartzite also occupy a considerable area of ground on the west side of Strath Carron, between Achnashellach and the margin of the map, and are succeeded in normal sequence by the Fucoid Beds and Serpulite Grit at Balnacra, Coulags and on the lower slopes of Cnoc na h-Àtha. Masses of the same strata, repeated by innumerable small thrusts, appear from beneath the Kishorn thrust-plane at intervals between the northern slopes of Glas Bheinn and Balnacra in Strath Carron, and rest upon a "sole" which overrides both the Fucoid Beds and the quartzites.

L. W. H.

In the disturbed area west of the Kinlochewe thrust, between Kinlochewe and Achnashellach, the normal type of sedimentation of

the Cambrian quartzites is remarkably persistent. In the case of the false-bedded grits one slight departure has been recorded in the Beinn Eighe Forest where a zone of grey shale, 13 ft. in thickness, occurs near the base of this subgroup. All the zones of the pipe-rock have been detected in this region and have been of great service in unravelling the complicated stratigraphy. The Fucoid Beds and *Salterella* (Serpulite) Grit are traceable through parts of the Coulin and Achnashellach forests, where they are reduplicated in places by folding and reversed faults. Of special importance is the occurrence in the Fucoid Beds of a band of pisolitic ironstone, from 18 in. to 2 ft. thick, in the Allt nan Dearcag, one of the sources of the Coulin River, at a point about two miles north from Achnashellach station.* There can be no doubt that it represents the layer of pisolitic ironstone in the same subgroup on the northern slopes of Meall a' Ghiubhais which yielded to Mr. Macconochie remains of trilobites and echinoderms.† The band at Allt nan Dearcag contains *Hyolithes*, and under the microscope plates of *Eocystites* and fragments of the tests of trilobites have been observed. J. H.

* J. Horne, *Trans. Geol. Soc. Edin.*, vol. vii. p. 113.

† "The Geological Structure of the North-West Highlands of Scotland," *Mem. Geol. Survey*, 1907, p. 414.

CHAPTER IV.

TECTONICS OF THE AREA WEST OF THE MOINE THRUST.

THE structure of the area west of the Moine thrust can be most readily explained by a series of horizontal sections drawn across the belt of disturbed country.

The complicated region between Kinlochewe and Achnashellach station has been described in detail and illustrated by several horizontal sections in the Memoir on "The Geological Structure of the North-West Highlands of Scotland." One of these is here reproduced with a condensed description to show the fan-shaped structure of the plicated strata in Sgùrr Dubh, the folded Torridonian rocks above the Kinlochewe thrust-plane in the Coulin Forest and the schists intermediate between the altered Torridon beds to the west and the typical granulitic Moine schists to the east.

Fig. 1.—At the west end of the section a hill of Lewisian Gneiss protrudes through the red sandstones to a height of 800 ft. On Liathach the great pile of Torridon Sandstone has been thrown into a flat arch, the beds being capped by outliers of Cambrian quartzite, including the false-bedded grits (Ca) and part of the pipe-rock (Cb).

On Sgùrr Dubh (2566 ft.) the Torridon Sandstone and basal quartzite display incipient fan-structure, the beds being inverted and repeated by minor thrusts on the western declivity. On the crest of the mountain infolds of the lowest sub-zone of the pipe-rock (Cb) have survived. The eastern slope reveals several compound flexures of the red sandstones and overlying quartzite. South-eastwards beyond the slope drained by the two tributaries of Allt na Luib, where the usual repetition may be seen of both divisions of the arenaceous series (Ca, Cb), the western flank of the hill that overlooks Loch Coulin presents the outcrop of the Kinlochewe thrust-plane (see Fig. 1).

Above this line of disruption the members of the Diabaig group (Ba) of the Torridon Sandstone with cores of Lewisian Gneiss are arranged in isoclinal folds that dip to the E.S.E. at angles varying from 15° to 36°. Several of these gneiss lenticles cannot be traced far, but the most easterly one forms a continuous band extending southwards from Loch Coulin and across Cnoc Daimh to Easan Dorcha. The thrust Torridon beds exposed on the hill west of the keeper's house at Coulin and in Allt Cnoc Daimh show an increase in the grade of metamorphism as the rocks are followed eastwards from the Kinlochewe thrust-plane. In the case of the two most westerly folds of Lewisian Gneiss the surrounding epidotic grits and shales are now much deformed, but on the east limb of the third arch of gneiss the epidotic grits are in an intensely sheared condition with abundant sericitic mica and secondary magnetite. Five

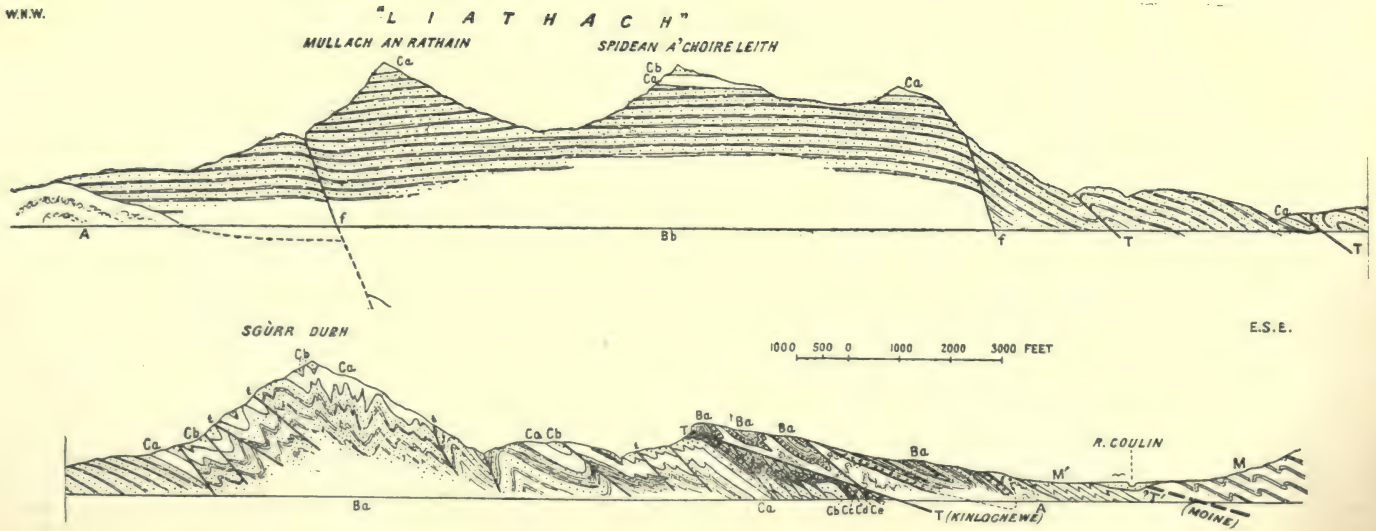

FIG. 1.—Section from Liathach by Sgùr Dubh to the river Coulin.

A. Lewisian Gneiss. Ba. Diabaig group (Torridonian). Bb. Applecross group. Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid Beds. Cd. Serpulite Grit. Ce. Limestone. M'. Mylonised Rocks, Phyllites, and Siliceous Schists. M. Moine Schist. T. Thrusts. ?T'. Moine thrust. t. Minor thrusts. f. Faults. ~ Alluvium.

hundred yards further east a fourth fold of Lewisian Gneiss, the most easterly of the series, appears, underlaid by similar sheared epidotic grits which are clearly displayed in the Cnoc Daimh Burn. Below the 800 ft. level in that stream an almost continuous section has been laid bare of the grey and black slaty shales, flags, and epidotic grits, dipping eastwards in inverted order at angles varying from 10° to 12°. The grits are sheared and their quartz grains more or less granulitised. Not far below the 500 ft. level the Lewisian Gneiss overlies the inverted basal conglomerate of the Diabaig group, the gritty matrix of which is intensely sheared and contains epidote, chlorite and magnetite (see Fig. 1).

The acid gneiss with basic lenticles which overlies this basal conglomerate has been so intensely crushed that it has been described by Dr. Teall as having the appearance of a clastic rock with much secondary mylonitic material. It is visible in the stream at the bend below the 500 ft. contour-line. Below it for a distance of 250 yds. the stream exposes a continuous section of strata of sedimentary origin, resting on the deformed Lewisian Gneiss, and presenting slightly different characters from the Diabaig beds in the inverted limb of the arch. At its upper margin the epidotic gneiss is practically a mylonite, thus indicating a plane of movement at this horizon. It is immediately succeeded by fine-grained, dark platy schist, which Dr. Teall finds to be composed of quartz, felspar, sericitic mica, small scales of brown mica and minute grains of epidote. He further notes that "under a low power this rock resembles a sandy shale, but under a high power the structure is more allied to that of a crystalline schist. It is difficult to avoid the conclusion that this is one of the sandy shales of the Torridon System." It may be remarked that this platy rock has the alternating dark and grey films so characteristic of the shaly bands of the Diabaig group, but the basal conglomerate, so well developed on the inverted limb of the arch, is here unrepresented.

About the 400 ft. level these dark platy schists contain a few garnets, and farther down-stream they are succeeded by fine-grained, grey, siliceous schists with scattered "eyes" of felspar. Dr. Teall remarks of this rock that it "appears to be a sheared epidotic grit, and, like the previous finer-grained rocks, is intermediate in structure between a normal sediment and a true crystalline schist." The precise geological horizon of these intermediate strata (M^1 in Fig. 1) is uncertain. If they represent the basal beds of the Diabaig group, it is obvious that they mark a higher grade of metamorphism than the same bands of the inverted limb of the arch. Beyond the alluvium of the river Coulin the normal granulitic schists of the Moine Series make their appearance, the outcrop of the Moine dislacement being not improbably concealed under the alluvium.

J. H.

Fig. 2.—At the west end of this section the Cambrian quartzites (Ca) of the Beinn Damh outlier (which barely touch the edge of the map) rest unconformably upon the Torridon Sandstone (Bb). On the steep eastern face of the mountain the sandstones dip west at a high angle beneath the gently-inclined quartzite, but further down the slope the inclination rapidly lessens towards a great anticlinal fold whose axis follows the line of Strath a' Bhàthaich, the valley

between Beinn Damh and Maol Chean-dearg, till on the further side of the valley the beds dip to the south-east. A short distance up the south-eastern slope of the same valley the western boundary of the disturbed area is marked by the outcrop of the first major thrust, by which a wedge of Torridonian and Cambrian strata has been brought in along the lower part of the steep face of Maol Chean-dearg. The two zones of the quartzite (Ca, Cb), are introduced by a sharp inverted fold which includes a number of minor plications. The eastern limb of this fold is truncated by the next major thrust, which has carried westwards more than 1000 ft. of Torridonian rocks. The upper portion of this mass belongs to the Cailleach Head group (III.) of the Torridonian Series.

On the eastern slope of the mountain the red sandstones are again succeeded unconformably by the Cambrian pipe-rock and basal quartzite, which are repeated by normal and inverted folds cut off on the east by minor thrusts. A few yards to the east of the second of these thrusts the Torridon sandstones once more make their appearance and rest in an inverted position upon the basal quartzite, both dipping south-east at angles of 25° to 30°. The folded and inverted junction is well seen in the cliffs two-thirds of a mile north of the loch at the head of Allt nan Ceapairean, the stream draining the eastern slope of An Ruadh-stac.

For 2 miles eastward from this point the ground is occupied by isoclinally-folded Torridonian strata dipping uniformly S.E.-S.S.E. at an average angle of 15°. On the east side of the Coire Fionnaraich glen the basal quartzite and pipe-rock of the Cambrian again appear in natural sequence, followed in places by the Fucoid Beds cropping out at intervals beneath a cake of thrust material which, brought forward upon two successive thrust-planes, covers the eastern slope of Càrn Eididh and descends to the road-side between Coulags and Balnacra in Strath Carron.

Upon the first of these thrust-planes rest the Fucoid Beds and Serpulite Grit of the Cambrian Series, repeated and driven together by numerous reversed faults. These strata are in turn over-ridden by the Kishorn thrust, which has brought forward from the east a mass of mylonised, flaggy Lewisian Gneiss (A).

The gneiss upon this maximum thrust-plane overlaps in places both the piled-up strata below and the Fucoid Beds upon which these strata lie, and rests directly upon the pipe-rock.

East of the Carron valley the granulitic quartzose schists of the Moine Series (M) with inliers of Lewisian Gneiss (A) are represented. The probable position of the Moine thrust is indicated beneath the alluvial deposits of the river Carron. L. W. H.

In the ground a short distance to the south of that described in the foregoing section the structure of the disturbed belt increases in complexity. The sandstones which overlie the first thrust-plane a little to the east of Loch na Sùileig are succeeded unconformably by the Cambrian quartzites which have been thrown into a double isoclinal fold on the lower slopes of An Ruadh-stac, whereby the outcrops of the pipe-rock and basal quartzite are repeated. Further up the hillside the eastern limb of this fold is truncated by the second major thrust, which again brings forward a mass of Torri-

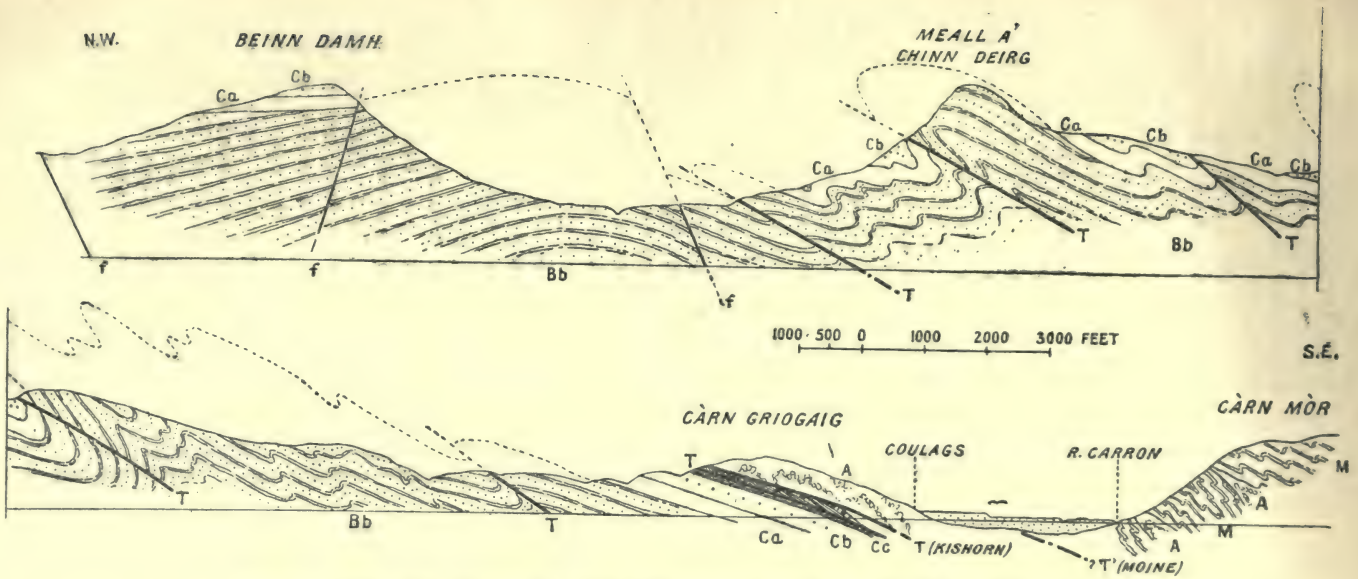

FIG. 2.—Section from Beinn Damh across Meall a' Chinn Deirg to Coulags in Strath Carron.*

A. Lewisian Gneiss. Bb. Applecross group (Torridonian). Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid Beds.
M. Eastern Schists. T. Thrusts. ?T'. Moine thrust. f. Faults. Alluvium.

* Two of the names in this figure—Meall a' Chinn Deirg and Carn Griogaig—have been changed respectively into Maol Chean-dearg and Carn Eididh on the latest edition of Sheet 82. A corresponding alteration has been made in the letterpress, but the figure, which is taken from the Survey Memoir on the Geological Structure of the North-West Highlands, has not been redrawn.

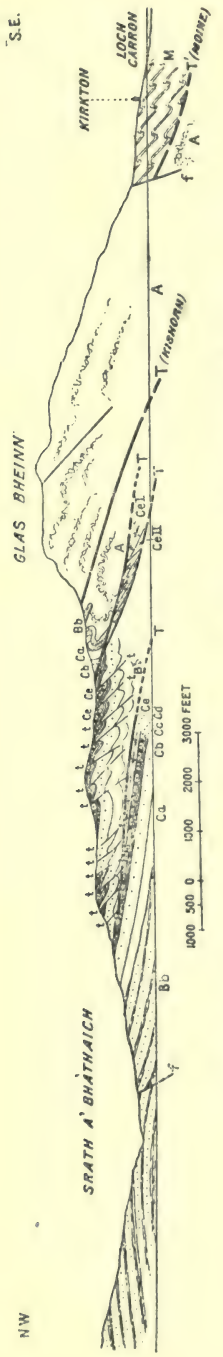

FIG. 3.—Section from Srath a' Bhathaich by Glas Bheinn to Kirkton on Loch Carron.

A. Lewisian Gneiss. Bb. Applecross group (Torridonian). Ca. Basal Quartzite (Cambrian). Cb. Pipe-rock. Cc. Fucoid Beds.
Cd. Serpulite Grit. Ce. Limestone. Ce I. Limestone (Ghrudaidh group). Ce II. Limestone (Eilean Dubh group).
M. Eastern Schists. T. Thrusts. T'. Moine thrust. t. Minor thrusts. f. Faults.

donian and Cambrian strata. The quartzites that form the crest and steep eastern face of the mountain are arranged in a series of complex isoclinal folds, most of which are cut off to the east by small thrusts. The intensity of the folding is well illustrated on the bare glaciated ridge between An Ruadh-stac and Loch Cadh' an Eididh, where the subzones of the pipe-rock can be distinctly traced. From the foot of An Ruadh-stac to Strath Carron the arrangement of the rocks is similar to that found in the eastern part of the section last described (Fig. 2).

The increasing complexity of the structure to the south may be further illustrated by another section (Fig. 3) drawn from An Gorm-loch in a south-easterly direction across the ridge of Glas Bheinn to the head of Loch Carron.

The north-western end of the section is similar to that of the section illustrated by Fig. 2. South of An Gorm-loch, above the two first major thrust-planes, a considerable area at the head of the pass to Strath Carron is occupied by a mass of Fucoid Beds, Serpulite Grit, and basal limestone, repeated by minor thrusts and driven together in great complexity.

A short distance west of the head of the pass these piled-up strata are overlapped by a thrust-plane on which the Cambrian quartzites have been carried westwards. On the watershed close to the margin of the map the pipe-rock dips at a high angle beneath the basal quartzite, which is in turn followed by inverted Torridonian grits, and these again by Lewisian Gneiss. The double unconformability is thus represented here in inverted order. Owing to folding and crushing the boundary lines of the different rocks are much involved, and it is besides often extremely difficult to separate the

basement breccia of the Torridonian, made up of fragments of gneiss, from the gneiss itself.

On the south side of the pass rise the steep craggy sides of Glas Bheinn, a mass of Lewisian Gneiss carried westwards upon the Kishorn thrust. This great line of dislocation runs northwards from Loch Kishorn in the adjoining Sheet (81), sweeps eastwards along the base of Glas Bheinn and across the head of the Tullich Glen, and finally descends to the valley of the river Carron near Coulags.

The actual plane of the thrust is laid bare along the stream that flows eastwards from the head of the Tullich pass into the Amhainn Bhuachaig, where the water follows the line between the quartzite below and the mylonised gneiss above.

The materials driven forward upon this great thrust-plane consist of Lewisian Gneiss (A) and portions of the lowest Torridonian group (Diabaig). The two formations preserve their unconformable relations, but in inverted order, so that the gneiss rests upon the younger rock and forms the highest part of the hill.*

The nature of the rocks above and below the Kishorn thrust are also discussed in Chapter III. p. 13. L. W. H.

* The above descriptions of sections across the disturbed area are condensed from those given in the Memoir on "The Geological Structure of the N.W. Highlands", (*Mem. Geol. Survey*), 1907, ch. xxxviii.

CHAPTER V.

METAMORPHIC ROCKS EAST OF THE MOINE THRUST.

THE metamorphic rocks of the area east of the Moine thrust-plane can be divided into two distinct series. Evidence in support of the belief that these rock groups belong to two different periods, and are in unconformable relation to one another, will be brought forward in the following pages.

GROUP A. A complex of acid, basic and ultra-basic gneisses essentially of Lewisian type, and closely resembling the rocks in certain parts of the Lewisian area of the north-west Highlands.

„ B. The Moine Series, comprising quartzose schists or quartz-biotite-granulites, and garnetiferous mica-schists or pelitic gneiss, representing respectively metamorphosed siliceous and argillaceous sediments.

The rocks of Group A, which will be referred to in the sequel as the Lewisian Gneiss, are for the most part of igneous origin—orthogneisses. These include acid felspathic gneisses, in which biotite is the only ferromagnesian mineral, biotite-hornblende-gneisses and pyroxene-hornblende-gneisses—all of which may be regarded as parts of the original complex. Garnetiferous hornblende-gneiss and amphibolite, eclogite, and hornblende-peridotite sheared into talcose chlorite-tremolite-schist, occur in irregular masses or in dyke-like bands, some of which certainly represent early basic and ultra-basic intrusions into the Fundamental Complex.

There is also present in most of the inliers a group of altered sedimentary rocks—paragneisses, comprising crystalline limestone, calc-silicate-rocks, and dark mica-schists that are often graphitic.

A detailed petrographical description of the Lewisian Gneisses will be found in Chapter VII.

B. The following zones and sub-zones have been established in the Moine Series and hold generally for the whole area, though local variations may occur in certain districts. They appear to rest in descending order as follows :—

Upper Siliceous Zone	b_5	Semi-pelitic sub-zone. Fine-grained quartz-biotite-granulites, in which the biotite is abundantly disseminated in small flakes through the rock.
	b_4	Massive siliceous granulites, often highly felspathic with pebbly bands.
	b_3	Flaggy siliceous schists, with thin partings of pelitic schist—"Moine Flags."

Pelitic Zone	b_2	Garnetiferous muscovite-biotite-gneiss or schist—"Pelitic Gneiss."
Lower Siliceous Zone	b_1	Flaggy, very siliceous schists; sometimes containing pale-green muscovite and small pale-coloured garnets.

In addition to the above, the local base of the series is in places conglomeratic. The rocks of both groups are, over almost the whole of the area, entirely granulitic, and possess a common foliation which has in most cases obliterated the original structures. In a few localities, however, mentioned in the sequel, traces of an earlier foliation and system of folding can still be detected in the Lewisian Gneiss (A), which do not pass into the surrounding rocks of the Moine Series (B). L. W. H.

Deformation of the Rocks on Either Side of the Moine Thrust.—A study of the rocks above and to the east of the Moine thrust-plane, shows that they have been subjected to the same great movements of the earth's crust to which the tectonic structures of the region to the west of that line of dislocation are due.

The great isoclinal folds into which both the Moine Series and the Lewisian Gneiss have been thrown, the minor folds and puckerings, and the granulitisation and recrystallisation in Moine and Lewisian rocks alike, together represent only the intensified action of the same crustal movements. In this eastern region they were, however, exerted in a different layer of the crust, where the load was sufficient to prevent disruptive and cataclastic action, although the deformation was even greater in amount. In other words, the phenomena of the belt of thrusting are but a marginal phase, produced under less load, of the folding and consequent deformation that prevailed over the whole of the area of metamorphic rocks to the east of that belt.

In the immediate neighbourhood of the Moine thrust-plane and even on the west side of it—as shown by the Torridonian infolds on Cnoc Daimh in the Coulin Forest—the action was not wholly cataclastic, but included granulitisation and the building up of new minerals, such as muscovite and biotite (see p. 21). Dr. Teall has shown, with regard to the foliation of the Criffel granite, that in one and the same rock certain minerals may be deformed and pass into the granulitic stage, while others are left rigid enough to show the effect of cataclastic action.*

In the masses above the Moine thrust-plane, where the material of the Moine and Lewisian rocks is mostly in the granulitic stage, there are yet places where ungranulitised pebbles can be recognised in the former, and in the latter the breaking down of original structures that have not been entirely obliterated. These "relict structures" become fewer and fewer as we pass eastwards from the line of thrust, but it is seldom that they cannot be detected.

This increasing constructive metamorphism found eastwards from the Moine thrust-plane, and the increasing intensity of the destructive deformation as we approach it from the west, seem to be more than analogues of one another. They may both be regarded as the effects of the same forces acting under different conditions, but with a sudden transition, along the outcrop of the Moine thrust-

* "The Silurian Rocks of Britain," *Mem. Geol. Survey*, vol. i. ch. xxvi. p. 609.

plane, from the one stage of alteration to the other. It is possible that, were the rocks on the east side of the line sufficiently denuded, a regular gradation in the amount of deformation to the eastward would be found.

It must be admitted that there is evidence of crushing of some of the "Moine" structures along the Moine thrust-plane west of Loch Carron, but the remains of pebbles in the Moine rocks show that they had not been entirely out of the region of cataclastic action even before they were brought under the direct influence of the Moine thrust. The friction along a thrust-plane would produce drag, with the result that portions of the advancing mass of Moine schist, originally situated further and further away from the thrust-plane, would successively override those portions in advance, until the former were eventually brought within the zone of crushing along the thrust-plane. The structures impressed upon the rocks from their subjection to different conditions during the one continuous movement might easily account for the late breaking down of structures produced at a rather earlier time during the movements. This is on the supposition that the movements were continuous both as to rate and time, which may not have been the case.

It is well known that pitch, resin or even limestone can be easily deformed without actual fracture by slow compression; while, if the rate be increased only very slightly, the material shatters.

The temperature of the masses may have been considerably raised by movement. If this movement was intermittent there may have been time for loss of temperature through several causes—conductivity, change in molecular structure, or chemical action. On movement being resumed the rocks would be more rigid, and crushing would take place.

Had there been perfect flow of the rocks there would have been no Moine thrust-plane. Its very presence implies a certain amount of rigidity of the rocks on both sides.

The outcrop of the Moine thrust-plane is well exposed west of the Carron valley in a small stream immediately to the north-west of Lochcarron village, at a point 200 yds. north of the bend made by the high road to Applecross and close to the edge of the map. At this point a clean-cut plane separates fine-grained, flaggy, quartzose Moine schist above from crushed, mylonitic, Lewisian gneiss beneath. The E.S.E. dip of the plane down the stream does not exceed 5° to 10°. The flaggy Moine schists above are disturbed, folded, broken and drawn out near the thrust-plane in such a manner as to leave no doubt that they were subjected to movement after having acquired their present state of crystallisation. Along the actual line of junction there is sometimes a pellicle, $\frac{1}{4}$ to $\frac{1}{2}$ inch thick, of crushed material, which may be a mixture of both the overlying and underlying rocks.

Analogous to the breaking down of the crystalline Moine flags above the thrust-plane is the folding and crushing of the already-made, platy, mylonitic rocks beneath, for some few feet down from the thrust-plane, as if these platy mylonites had been dragged forward by the overlying Moine schists. In other words, both the Moine schists and the platy mylonites show that they have been further affected by the last movements that occurred along the

thrust-plane, and therefore owe their respectively crystalline and platy condition to a different phase in the movement from that which brought them into their present conjunction.

Metamorphism.—Evidence of increasing metamorphism in the rocks above the Moine thrust-plane as they are traced eastwards from its outcrop can be found in many parts of the area. At Loch-carron village, in the extreme west, the Moine schists contain pebbly calcareous rocks—"calcareous grit." In the pebbly rocks on Sgeir Chreagach, an island in Loch Carron, the cores of the larger quartz grains are still of unaltered blue quartz, with a peripheral layer of granulitic matter. Further to the east, in the more altered coarse-grained Moine schists beyond Strath Carron, the larger felspars similarly represent the remains of the original clastic grains, and show a core of ungranulitised material.

The pelitic sediments of the Moine Series are represented on the west side of Loch Carron by lustrous slates and fine-grained phyllites. On Sgeir Fhada these contain small garnets, while across the loch at Attadale they have passed into fine-grained muscovite-biotite-schists, in some bands of which rounded quartz-felspar aggregates have been developed. When the central belt of pelitic rocks, which stretches from Achnasheen to Beinn Dronaig, is reached, they are in the condition of typical muscovite-biotite-gneiss; and both in these and in the neighbouring siliceous granulites, there is much segregation of muscovite-pegmatites.

A similar increase in the stage of metamorphism of the Lewisian gneisses is met with in passing eastwards from the Moine thrust-plane over the successive inliers.

At Attadale, the whole of the rocks are finely granulitic, a texture obviously superinduced upon a more coarsely crystalline condition of the component minerals, many of the rocks being actually in the condition of those that occur along lines of special movement in the Loch Inver region (granulitic hornblende-gneiss) while others resemble the zoisite-gneiss of Sangomore and the Fair-aird Head near Durness, and of Loch Eireboll.* Chlorite and actinolite are the common ferromagnesian minerals, and epidote is almost always present. In the successive inliers met with in the east of the map, a more complete reconstruction of the crystalline structure has taken place, and various new chemical combinations have been set up.† All the rocks are in the "granoblastic" stage, the granules being comparatively large, though almost all of equal size and with no definite crystalline form. The hornblende is granular rather than acicular, and pyroxene is formed, evidently at the expense of the hornblende.

Unconformable Relations of the Moine Series to the Lewisian Gneiss.

Good evidence of the unconformity between these two formations is found in the area immediately to the south and west of Attadale. The following definite local order of sequence in the rocks of the

* "The N.W. Highlands of Scotland," *Mem. Geol. Survey*, 1907, ch. viii. p. 116.

† "Summary of Progress for 1905," *Mem. Geol. Survey*, 1906, App. p. 158.

Moine Series is encountered in passing outwards from the margin of the Lewisian masses in the neighbourhood of Attadale (see next page, Fig. 4).

(*c*) Flaggy siliceous granulitic schists.
(*b*) Mica-schist with muscovite and biotite, and in some bands, radiating actinolite.
(*a*) Conglomeratic rock composed of irregularly foliated micaceous and sometimes actinolitic schist, containing fusiform fragments of granulitic gneiss like the more acid portion of the adjoining Lewisian rocks.*

The rocks of zone (*a*) are not always present at the junction, and their place is sometimes taken by those of (*b*). When all are present, however, the above is invariably the order of sequence. A few miles south of Attadale both the lower groups are absent, and the granulites of (*c*) are in contact with the gneiss, an arrangement suggestive of overlap as well as unconformability.

The strongest evidence can be brought forward against the supposition that the Lewisian Gneiss may be an igneous intrusion in the Moine Series. The extremely complex nature of the various inliers of Lewisian Gneiss, into which enter acid, basic and ultra-basic rocks of several different periods, is in itself enough to preclude the idea of a simple igneous intrusion, to which may be added the sharp nature of the junctions between the two rocks and the entire absence of anything like apophyses of the Lewisian Gneiss penetrating the altered sediments.

It can also be shown (by the mapping) that the original relations of the two series of rocks were established before the great crustal movements which produced the overfolding and granulitisation common to both formations.

Additional evidence of unconformable relation is afforded by the position and lithological character of the altered sedimentary rocks—paragneisses, which occur in several of the Lewisian inliers in the

* This rock bears a striking resemblance to the basal conglomerate found in the successive infolds of Torridonian rocks of the Diabaig group that are involved in the crushed gneiss below the Moine thrust-plane in the region between Strome Ferry and Balmacara (Sheet 71).† The difference between the two rocks consists in the extent to which reconstruction has gone on in the conglomerate of (*a*). The matrix of that rock is holocrystalline, as well as granulitic, and some of the actinolite crystals pass from it into the periphery of the included fragments. Some of these fragments are not, however, wholly reconstructed, and still show in parts the effect of strain and crushing, and although in the Torridonian conglomerate of the infolds the cataclastic action is more apparent, they have also undergone a considerable amount of reconstruction, expressed both in granulitisation and in the production of new micas. A similar comparison can be drawn between the more pelitic rocks in both areas. The amount of secondary biotite set up in the phyllites of admitted Torridonian age on Cnoc Daimh, in the Achnashellach Forest, is such that they are indistinguishable from the phyllites associated with the quartzo-felspathic granulites above the supposed position of the Moine thrust-plane in that region.

The difference between the rocks of sedimentary origin on either side of the Moine thrust-plane in the Loch Carron region is thus shown to be one of degree of alteration and not of kind. B. N. P.

† "The Geology of Glenelg, Lochalsh and the South-East Part of Skye," *Mem. Geol. Survey*, 1910, ch. vi. p. 74.

centre of the map. They are arranged asymmetrically with regard to the periphery of the inlier, indicating that the gneiss had suffered

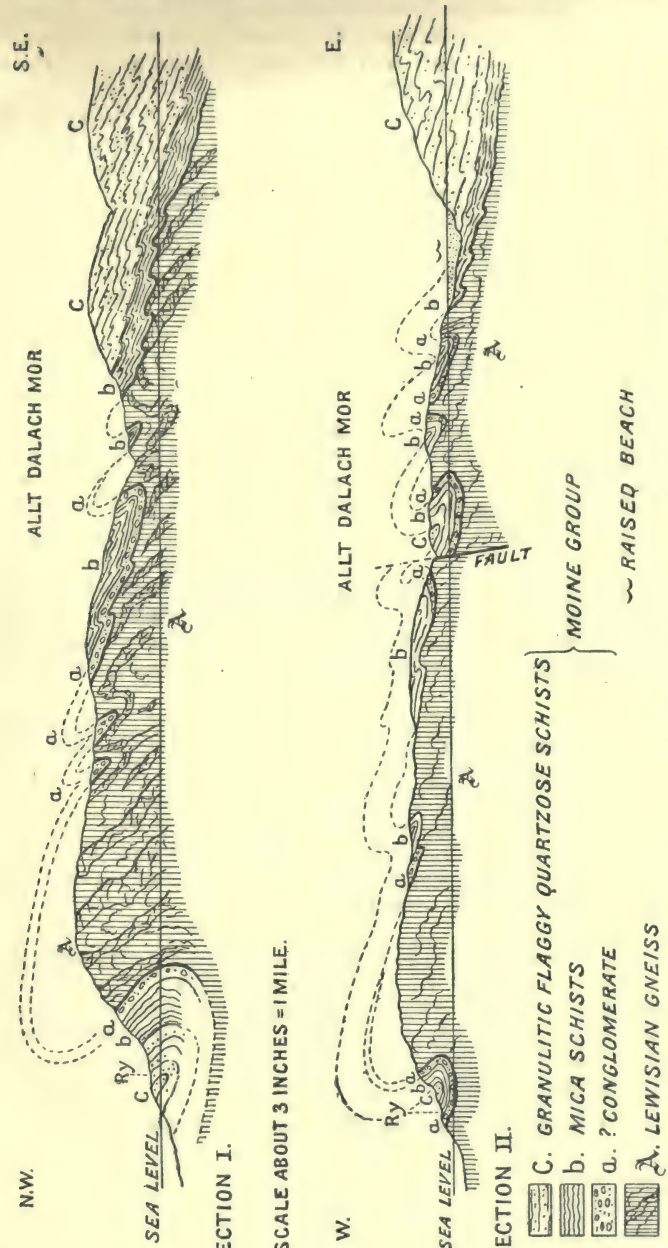

FIG. 4.—Diagrammatic Sections showing the Relations of the Rocks of the Moine Series to the Lewisian Gneiss in the ground south of Attadale, Loch Carron.

denudation prior to the deposition of the Moine sediments. Further, Dr. Flett has shown that these paragneisses have undergone a contact-

metamorphism due to the orthogneiss, which is not shared by the Moine rocks of similar composition near at hand. The same observer has detected a difference in texture between the acid rocks of similar composition in the two series, and also between the hornblende-schists and gneisses of the Lewisian complex and the sills of amphibolite which pierce the Moine schists.*

A distinct discordance between the beds that form the local base of the Moine Series and different members of the underlying Lewisian Gneiss can be observed at many places within the area. It is particularly well exemplified along the margin of the mass of gneiss south of Attadale, where there is everywhere evidence of the overlap of the Moine schists on to successive bands of hornblende-rock. Each of the latter is found to diverge, gently at first, from the junction-line, and then rapidly, as the band is followed outwards from the boundary.

This phenomenon is evidently produced by drag, the gneiss having yielded more readily to the subsequent movements than the overlying schists.

Such direct evidence of unconformity as is supplied by the presence of rocks, having all the appearance of conglomerates, at the junction of the two formations, is found in several of the eastern inliers, and will be described in the sections allotted to the different areas. B. N. P., L. W. H.

To sum up briefly the evidence brought forward in this chapter—

The Lewisian Gneiss is a complex of different rocks of different ages, and includes altered sedimentary rocks that were denuded and affected by contact-metamorphism before the deposition of the Moine sediments.

The sequence of zones in the Moine Series preserves a constant relation to the Lewisian Gneiss, but any zone may successively be in contact with the latter, while the same zone of the former may in turn overlap successive members of the Lewisian complex.

There is present at the base of the Moine Series, and resting on the Lewisian surface, a rock having all the appearance of a conglomerate and containing fragments of rock indistinguishable from members of the underlying complex.

Hence it may be concluded, with some degree of certainty, that the sediments of the Moine Series were laid down upon the denuded surface of an earlier complex of igneous and sedimentary rocks, and that both series have since been subjected to earth movements by which they have been folded and granulitised, and have received a foliation common to both. L. W. H.

* "Summary of Progress for 1905," *Mem. Geol. Survey*, 1906, App. p.165.

CHAPTER VI.

INLIERS OF LEWISIAN GNEISS.

Attadale.

The ground along the eastern side of Loch Carron, between Attadale and the south-western corner of the map, is occupied by the northern prolongation of an inlier of Lewisian rocks, forming the core of an isoclinal anticlinal fold, and flanked on either side by the schists of the Moine Series.

The central portion of the inlier consists mostly of a highly felspathic gneiss of a crude type, in which the foliation is faintly indicated by interrupted folia and lenticles of biotite and hornblende. This central mass is bounded on either side by a belt in which the rock has undergone increasing deformation, until, along the margin, it assumes a more or less rolled-out or platy character. Hornblende-rock in bands of varying breadth and large lenticular masses, and rocks which have the appearance of sheared pegmatite, make up a considerable proportion of the inlier, the basic rocks being most abundant along the western side of the area.

In one of the small burns which falls down the steep hillside into the sea at Ardnarff, the gneiss contains a band of soft talcose calc-schist, consisting of about equal parts of greenish talc and granular carbonates. It probably represents an ultra-basic rock profoundly modified.

Along its western margin the gneiss is in contact with a platy dark grey mica-schist containing drawn-out lenticles of quartzo-felspathic material. This is considered to represent the pelitic gneiss of the Moine Series, and is succeeded above by siliceous schists of the same series. A similar sequence is found along the eastern margin of the inlier, but at a point 1 mile S.S.W. of Loch an Iasaich, and close to the edge of the map, the siliceous schist appears to overlap the grey mica-schist, so that the Lewisian Gneiss is here in contact with the higher member of the Moine Series.

Achnasheen.

In the neighbourhood of Achnasheen there are several small inliers of acid and basic gneiss which may be considered to belong to the orthogneisses of the Lewisian complex.

The largest of these is found on the south-eastern slope of Creagan nan Laogh, and the rocks of which it is composed are well seen in the burn which flows down the hillside a mile east of Achnasheen station. On its northern or higher side the gneiss of

the inlier is in contact with the pelitic gneiss (b_2), on its down-stream side with flaggy siliceous schists which are referred to (b_1), the lowest zone of the Moine Series.

Other small outliers of gneiss of Lewisian type occur on the summit and northern slopes of An Liathanach, above Loch a' Chroisg.

L. W. H.

Valley of the Meig—The Scardroy Inlier.

The largest continuous area of Lewisian Gneiss east of the Moine thrust-plane occupies the valley of the river Meig from a point 4 miles above Scardroy to the foot of Loch Beannacharain, and extends northwards and eastwards over Càrn Chaorain and Leanaidh to the northern flanks of Sgùrr a' Ghlas Leathaid. The predominant rock type over the greater part of this area is a thoroughly granulitic, pinkish, felspathic gneiss, with thin folia of biotite-gneiss, biotite-hornblende-gneiss, and hornblende-gneiss. In many places the more basic bands increase in breadth and frequency until the rock passes into a well-banded rock with rapid alternations of acid and basic material.

Irregular masses of basic and ultra-basic material occupy a considerable area and may be regarded as representing early intrusions into the original complex. An example of the latter is found on the hillside above Loch Beannacharain, ¾ mile N.N.W. of Carnoch. The original rock appears to have been a hornblende-peridotite, but the greater part of the mass is now sheared into a talcose chlorite-tremolite-schist. The largest mass of basic rock forms the crags and summit of Coir' a' Bhuic to the south of the small loch of that name, 2 miles west of Scardroy; and extends northwards to Càrn Mhàrtuin, where it is cut off and shifted eastwards by the Glen Docherty fault.

The rock may be described in general terms as a garnetiferous hornblende-gneiss, but the amount of foliation varies much in different parts of the mass. In some very little parallel structure can be detected, and the rock is entirely made up of hornblende and large rounded garnet aggregates. In others it is well foliated and tolerably felspathic, while there are many lines of special movement along which the rock passes into a fine-grained hornblende-schist or chlorite-schist. Portions of the mass are very rich in epidote, forming oval light green patches mixed with felspar, which are very conspicuous against the darker colour of the groundmass.

A belt with parallel bands of dark hornblende-biotite-gneiss so numerous and close together as to make up the greater part of the rock, extends with a persistent N.N.W. trend over Càrn an Leanaidh from the head of Loch Beannacharain. These bands possibly represent early basic dyke-intrusions, although their intrusive nature has been almost completely obliterated by subsequent movement. Associated with these hornblendic bands is a narrow lenticular mass of thoroughly foliated ultra-basic rock.*

A dyke-like band of hornblende-gneiss, well foliated at the

* In his description of these hornblende-biotite-gneisses Dr. Flett refers to the abundance of yellow epidote and the presence of orthite, as pointing to their connection with the Lewisian Gneiss rather than with the Moine Series, in which these minerals are rare. "Summary of Progress for 1905," *Mem. Geol. Survey*, 1906, App. p. 159.

margins but coarser and more massive in the centre, is in contact with the hornblende-peridotite near Carnoch, mentioned in an earlier paragraph. The ultra-basic appears to be cut by the basic rock, but the relations of the two masses are somewhat obscure. Certain bands of the hornblende-gneiss are full of garnets, some of which are drawn out along the planes of movement, while others are idiomorphic.

The banded gneiss and garnetiferous amphibolites are well seen at the fall on the Meig below Scardroy, and along the road at the side of Loch Beannacharain.

Paragneisses, or altered rocks of sedimentary origin, forming part of the Lewisian complex, occur at two localities within this inlier: in the deep ravine cut by the Allt Coire Dubh, near the head of Loch Beannacharain, and in the bed of a small stream that falls from Cnap na Feòla into Gleann Méinich. Coarse-grained granular-crystalline limestones containing flakes of dark green biotite, and, in the Gleann Méinich rock, small crystals of bright green amphibole, occur in both localities, associated with calc-silicates. Among the latter is an interesting rock resembling a calc-silicate-hornfels, containing scapolite, and described by Dr. Flett as a scapolite-pyroxene-gneiss (12,393). Another rock associated with the limestone of Allt Coire Dubh is mainly composed of granular yellow epidote and pale green, perfectly fresh augite—"pyroxene-epidote-rock" (12,396).

Relations of the Lewisian Gneiss of the Scardroy inlier to the Moine Series.—On the south side of the inlier the gneiss is in contact for a distance of 4 miles with the pelitic zone (b^2) of the Moine Series, the boundary line between the two formations being marked by a conspicuous feature which closely follows the 1000 ft. contour along the slopes of Meall Buidhe.

The junction of the coarse pelitic gneiss with the underlying acid banded gneiss (A) can be seen in several of the small streams that fall down the hillside, and in one case the former is resting in contact with a band of hornblende-rock.

At the point where the boundary crosses the Meig just below the bridge at Corriefeol, the base of the pelitic gneiss is formed of a peculiar rock containing an abundance of hornblende in addition to biotite, and with rounded phacoids of gneissose material, suggestive of a derivative origin.

The western margin of the inlier, on the north side of Gleann Fhiodhaig, affords good evidence of the discordance between the two formations. On Creag na h-Iolaire the acid gneiss is in contact with massive siliceous granulites (b^4) of the Moine Series. From the top of the hill a broad band of the latter sweeps down over the crags into the bottom of Coir' a' Bhuic. On the summit and higher part of the corrie face the granulite rests upon the hornblende-gneiss of the basic mass described on p. 34, but near the foot of the crags is in contact once more with the acid banded gneisses that occupy the valley below. Half a mile further to the west a narrower strip of Moine quartz-granulite descends the hill-face in a similar manner. In its lower part it is in contact on both sides with the basic rock, but above the 1500 ft. contour it has on its western margin the finely banded acid gneisses that are well exposed in the headwaters of the Allt Mhàrtuin.

At the south-eastern end of the inlier the Lewisian margin is in contact with the pelitic gneiss (b^2) for some distance north of the river, but as that margin is followed up the steep slope of Meall na Faochaig, it is found to transgress the boundary between two zones of the Moine Series (b^1 and b^2) until from a point $\frac{3}{4}$ mile north of Carnoch the gneiss is continually in conjunction with the lower siliceous member of the series. The two formations can be traced together in close contiguity round the ends of the sharp isoclinal folds between Meall na Faochaig and the head of Gleann Méinich. A smaller inlier of banded acid and biotite-hornblende gneisses appears about half-way up Gleann Méinich and extends for half a mile up the hillside above the shepherd's house. It is entirely surrounded by flaggy siliceous granulites, that presumably belong to the lowest zone (b^1) of the Moine Series, while the sharp interfolding of the Lewisian and Moine rocks is well displayed around the northern extremity of the inlier.

It is obvious that here, as in all the other Lewisian areas east of the Moine thrust, both formations have been affected equally by the folding and share in the foliation superinduced upon the Moine sediments.

In a few localities in this region, however, as, for instance, at the foot of the crags in Coir' a' Bhuic, unobliterated original structures can be traced in the Lewisian Gneiss with which the foliation planes of the contiguous siliceous Moine schist are distinctly in discordance.

Glen Orrin.

Two belts of Lewisian Gneiss enter the eastern margin of the map on either side of the river Orrin and form part of the Glen Orrin inlier described in the Explanation accompanying the adjoining map (Sheet 83). The northern belt crosses the path from Inverchoran, the other follows the southern slopes of the glen to An Gorm-Loch, where the rapid isoclinal folding, and the relations of the gneiss to the members of the Moine Series, are finely displayed in the bare crags that rise above the head of the loch.

The predominant type of gneiss in these masses is a banded granulitic, acid, highly felspathic rock, the most acid portions being sometimes difficult to separate from the quartz-granulites of the Moine Series with which they are generally in contact. Some of the bands are very micaceous, and have white mica developed on the divisional planes. Alternating with the acid gneiss with varying frequency are bands of biotite-hornblende-, hornblende-, and more rarely pyroxene-hornblende-gneiss.

On the north side of the Orrin, above Loch na Caoidhe, are two smaller isolated inliers of gneiss, generally similar in character to that described above. Both these masses are involved along their western margins in the zone of crush that accompanies the Strathconon fault, and are consequently full of epidotic crush lines, along which the rock is shattered, brecciated and stained with hæmatite.

L. W. H.

Loch Monar to Gleann Fhiodhaig.

The northern prolongation of the Patt inlier across Loch Monar can be traced from the shore of the lake up the hillside above Réidh-cruaidh, in a series of small stream-sections showing vertical hornblendic gneisses with a well-marked band of white crystalline limestone. When followed along their strike towards the top of the hill, these gneisses are suddenly lost. They reappear in the stream-sections a mile and a half to the north-east, the lateral displacement being due to a large north-easterly fault which is visible in the Allt a' Choire Fhionnaraich, and forms a marked feature up the hill-slopes on either side of the stream.

In the Allt a' Chreagain Bhuidhe, and in its main tributary on the north bank, the hornblendic gneisses contain a band of white crystalline limestone, like that on the other side of the fault, together with bands of graphite and calc-silicate schists. Similar beds can be seen at intervals further north in the Allt a' Choire Fhionnaraich. These hornblendic gneisses are continuous with those of the Scardroy inlier, forming the hillsides at the mouth of Gleann Fhiodhaig, where the rocks in the main are made up of rapid alternations of hornblendic and pink quartzo-felspathic gneisses. In the river Meig, near the western boundary of the inlier, rusty-weathering bands, similar in appearance to the graphite-schists of the Patt inlier, were observed, though no limestone or calc-silicate-schists could be found.

Along the watershed north of the river Meig the hornblendic gneisses are separated from the large mass of garnet-amphibolite to the east by a narrow but persistent band of siliceous schist of the Moine type. On the hillside east of Creag na h-Iolaire several masses of garnet-amphibolite can be seen in both the Lewisian and Moine gneisses. But the intricate nature of the folding and the covering of drift obscure the relations of these amphibolites to the two rock-series.

Relations of the Lewisian Rocks to the Moine Series.—The rocks along the whole western boundary of the Scardroy inlier, between Cnoc an t-Sìthein and Loch Monar, are steeply folded, with a north-and-south strike. From the Allt na Crìche southwards the Lewisian rocks are in contact with the massive contorted granulites (b^4) of the Moine Series, as is also the case along the south-western boundary.

Important evidence as to the relation of the two series is afforded by the excellent stream-sections to the north-east of Maoile Choill'-mas at the extreme south-western corner of the Scardroy inlier.

The fullest development of the Lewisian Gneiss is seen in the Allt a' Chreagain Bhuidhe and its main northern tributary. Passing eastwards down these streams, the observer meets with, in succession (1) a band of massive garnet-amphibolite and hornblende-schist, (2) a few feet of white crystalline limestone, and (3) rapid alternations of hornblendic and acid gneisses containing beds of calc-silicate-rock and graphite-schists, beyond which the massive Moine granulites again appear. The strike of these beds is a little east of north, but as the sections are followed up the course of the Allt a' Choire Fhionnaraich only a part of the series is seen, the different

members of the Lewisian complex being successively transgressed by the Moine granulites. Passing northwards up the stream the Moine gneisses are found resting first on the graphite-schist, then on the calc-silicate bands, until finally, nearly 2 miles above Loch Monar, they are in contact with the garnet-amphibolite.

These sections thus afford clear evidence of the transgression of a single member of the Moine Series across several members of the Lewisian complex. The actual junction can be seen at several places; it is extremely sharp, but nothing in the nature of a conglomerate, nor any indication of thrusting, was observed.

Other junctions of the two series are visible further north, along the western boundary of the Scardroy inlier. There is a good section in the river Meig, and it is noteworthy that here a band with quartzo-felspathic augen, from 1 to 3 in. long, occurs at the base of the Moine granulites along the junction line. It is not, however, possible to determine whether these "augen" are the remnants of a true conglomerate or of crush-conglomerates due to shearing movements.

Good sections of the junction, marked by an inch or two of soft chloritic schist, can also be seen on the hillside south of the river.

R. G. C.

Monar Area.

Within the Monar area there are no less than six separate inliers of Lewisian Gneiss.

1. *The Patt inlier*—at the west end of Loch Monar. This mass is elongated in form, the long axis being parallel to the N.N.E.-S.S.W. strike of the rocks, and extends southward from Maoile Choill'mas, north of Loch Monar, for a distance of 3 miles to the lower slopes of Beinn Bheag, with a maximum width of about 1200 yds.

The inlier is surrounded by rocks of the siliceous Moine type. The general strike of the gneiss towards the foot of Beinn Bheag is south-west, and parallel to that of the Moine schists which form the higher ground, but the boundary between the two formations lies at right angles to that direction, thus conveying the idea that the siliceous schists are resting unconformably upon the complex gneisses.

The lower course of the Allt Riabhachain crosses this inlier and affords the only section in which the rock is exposed for any distance, the remainder of the ground being flat and mostly drift-covered. In the bed of that stream the rocks are isoclinally overfolded to the north-west with a persistent south-east dip at angles varying from 20° to 60°. For a distance of considerably over a mile the section consists of rapidly alternating dark and pale gneisses in strongly contrasting bands.

The dominant type contains hornblende and dark mica, while other bands consist chiefly of black hornblende, the different types alternating so rapidly as to give sometimes a banded appearance to the rock. Contrasting in colour with these are almost white gneisses which have all the appearance of sheared pegmatites and are chiefly composed of granulitic quartz and felspar. At one or two places in this section rocks resembling the Moine granulites are intercalated,

and probably represent infolds of the siliceous Moine group. A short distance east of this burn a smaller stream, unrepresented on the map, shows similar hornblende-biotite-gneisses, and, in close association with these, there is exposed at one point a band of marmorised limestone 3 ft. in thickness. This marble varies from almost pure white to green in colour, the latter being due to the great quantity of epidote present.

2. *Meallan Buidhe inlier.*—Another large inlier occupies the gentle slopes between Meallan Buidhe and An Riabhachan, and is crossed by the two most easterly branches of the Allt Riabhachain which drain the north flank of the latter mountain. The north-west boundary of this inlier is formed by the Strathconon fault, which brings the Lewisian gneisses against the siliceous Moine schists of Beinn Bheag for a distance of 2 miles. The ground rises to the south and east, and the margin of the gneiss is coterminous in these directions successively with two members of the Moine Series. The eastern boundary is irregular, the gneiss occupying the lower slopes and the siliceous Moines the higher ground of Meallan Buidhe along the same lines of strike. The line of junction is at right angles to the general strike, but conforms to the irregularities of the ground in such a manner as to indicate the super-position of the Moine rocks upon the gneisses of the inlier.

Further south, on the slopes of Riabhachan, the Lewisian Gneiss is in contact and interfolded with the pelitic schists (b_2) which form that mountain, the two groups having the same southerly dip at high angles.

The general surface of the inlier is covered by drift, but good sections are seen in all the burns, and especially in that one which drains the western shoulder of Meall Garbh.

The rocks are for the most part vertical, with a general east-and-west strike. They are of the same banded type as those of the Patt inlier, and consist of biotite- and hornblende-gneisses with sheared pegmatites; they have also associated with them ultra-basic rocks containing amphibole, pyroxene, talc and carbonate bands. A band of this type, 50 yds. in breadth, is exposed in two of the burn-sections. Dr. Flett regards this rock as perhaps representing the pyroxenite familiar in the Lewisian Gneiss of the west coast, but here metamorphosed by shearing.*

This ultra-basic rock appears in the field as a dark, greenish-grey, lustrous schist, very soapy to the touch. In its immediate neighbourhood is a broad band of white siliceous rock resembling a quartzite which may have originated as a quartz vein, and, like the sheared pegmatites, have undergone granulitisation. Unsheared pegmatites, resembling those of the Moine schists, are also seen in this section and must be of later origin than the sheared pegmatites and the movements to which the latter have been subjected. Another type of rock found in this inlier takes the form of broad bands of hornblende-schist, strongly resembling the sheared dykes of Scourie, on the west coast of Sutherland.

A band of marble similar in character to that of the Patt inlier occurs on the eastern flanks of Meallan Buidhe near the margin of the inlier.

* "Summary of Progress for 1905," *Mem. Geol. Survey*, 1906, p. 162.

3. *The An Cruachan inlier,* about a square mile in extent, covers the northern, eastern, and part of the southern flanks of An Cruachan, the summit of the hill being formed of siliceous schist. The Lewisian rocks reach an elevation of over 2000 ft. near the top of the mountain, but fall suddenly on the south-east side below the 1500 ft. contour-line, and are probably truncated at their southern end by the Strathconon wrench. The inlier has a north-and-south elongation, and lies on the line of a powerful "ruck" or axis of plication which passes northward towards Bidean an Eòin Deirg. The rock is well exposed on An Cruachan, and the junction of the Lewisian Gneiss with the siliceous Moine schist that caps the summit of the mountain is well seen. In addition to the usual types of hornblende- and biotite-schist, this inlier contains eclogite closely associated with a highly graphitic schist containing andalusite, and a brown biotite-schist which has some resemblance to the pelitic gneiss (b_2). These three types, like the limestone of the other inliers, have a strong resemblance to the rocks of the Glenelg district. The graphite-schist is of special interest, as it affords evidence that the sediments have undergone contact-alteration of the hornfels type. The An Cruachan inlier is surrounded on all sides by siliceous schists of the Moine Series, and the transgression of the different members of the Lewisian complex by these schists is clearly seen, the Moine rocks being in contact successively with the graphite-schist, the biotite-hornblende-gneiss and the brown mica-schist.

4. The fourth inlier forms an irregular strip, more than 3 miles in length, that extends northward from the east end of Meall Mòr across Strathmore, and along the western flank of Bidean an Eòin Deirg to the watershed, and on the north side descends into the corrie from which flow the headwaters of the Amhainn Srath Mhuilich. At 1200 ft. on the western end of Meall Mòr the rocks, which are chiefly biotite-gneisses, are vertical and strike N.N.W.-S.S.E., but the banding shows much crumpling. They follow the same line of "ruck" which has already been mentioned as crossing An Cruachan. A wider belt of similar rocks is exposed in the bed of the Strathmore River. On the northern slopes of Strathmore rocks of the same character are seen in the Allt Toll a' Chaorachain and in the burn about a quarter of a mile further to the east.

The narrow belt of Lewisian rocks that sweeps round the western and north-western face of Bidean an Eòin Deirg includes hornblende- and biotite-gneisses, bands rich in calc-silicates, and a thin band of ultra-basic talcose schist, the types of rock being similar to those of the other inliers.

5. Several smaller inliers of Lewisian Gneiss are exposed along the denuded core of the overfold of pelitic gneiss which crosses the West Monar Forest from Sgùrr a' Chaorachain to Beinn Dronaig.

The chief of these occur on the summit of Beinn Dronaig and on either side of Loch Calavie. The gneiss is here surrounded by the siliceous schists of (b_1) the lowest zone of the Moine Series.

The types of rock represented in the Beinn Dronaig inliers include hornblende-biotite-gneisses, eclogites, and brown mica-schists

similar to those of the An Cruachan inlier. No graphite-schist has been detected.

Other small exposures of hornblende-biotite-gneiss occur on the southern flank of Sgùrr a' Chaorachain and in the corrie facing south between Meall Mòr and Lurg Mhòr. In the latter locality talcose ultra-basic rocks are associated with them. Both these exposures are surrounded by pelitic gneiss.

6. The largest Lewisian inlier in the Monar district lies between the eastern end of An Riabhachan, Sgùrr na Lapaich and Sgùrr na Muice on the north side of the river Farrar. Hornblende- and biotite-gneisses are exposed on the floor of the corrie between Sgùrr na Lapaich and Meall Garbh, and pass eastward in a band about 300 yards in width along the northern slopes of Sgùrr na Lapaich. After a distance of a mile the outcrop increases in breadth and the northern boundary follows the course of the Uisge Misgeach, being parallel to the general strike of the Lewisian Gneiss and the siliceous schists with which the former is now in contact, the boundary having transgressed from the pelitic to the siliceous zone of the Moine Series, ¼ mile to the east of Allt an Eas Bhain Mhòir. The southern margin of the inlier bends to the south over the north-east shoulder of Sgùrr na Lapaich, and, crossing the ridge, plunges nearly a thousand feet to the bottom of the Garbh-choire on the east face of the mountain. Small synclinal folds of the pelitic gneiss (b_2) rest on the Lewisian rocks along the junction of the two rocks, where the boundary line crosses the shoulder of Sgùrr na Lapaich.

An almost continuous Lewisian section is exposed for a distance of over a mile along the course of the Allt Garbh-choire. The long range of cliffs on the shoulder of Sgùrr na Lapaich, that rise above this burn on the west, have all the massive appearance that characterises the Lewisian Gneiss landscapes of the north-west Highlands. Rocks of the ultra-basic type exposed in the cliffs and in the bed of the burn have the same talcose character as in the other inliers, and have presumably undergone an equal amount of metamorphism. The other rock types here met with are hornblende- and hornblende-biotite-gneisses, sheared pegmatites, hornblende-schists, calc-silicate-rocks and brown mica-schists.

On the top of the wooded ridge in the angle between the Allt Garbh-choire and the Uisge Misgeach stream, lenticular patches of a conglomeratic rock rest upon the gneiss. These patches follow the same line of strike as the band of conglomeratic rock which crosses Càrn Mòr, farther east, and is described elsewhere (p. 67).

The rock is of a highly siliceous Moine type, containing what appear to be drawn-out fragments and pebbles of pegmatite. A small exposure of a similar rock in the bed of the Allt Garbh-choire close by shows also knots of hornblende, which appear to have a derivative origin. C. B. C.

Glen Strath Farrar.

The continuation of this inlier (No. 6) which crosses the river Farrar above Broulin Lodge includes a diversity of rock types, many of which are not met with in the surrounding Moine Series. What

more than anything, however, serves to distinguish the two formations is the almost universal presence, in the former, of bands and lenticles of hornblende-schist. Bands of hornblende-schist outwardly resembling those in the Lewisian Gneiss occur, it is true, in certain parts of the Moine schists of the same neighbourhood, but never in such numbers nor so thickly distributed over wide areas.

The whole series of metamorphic rocks composing the inlier may for descriptive purposes be divided into three groups.

(1) Those which from their mineralogical and chemical composition are certainly paragneisses or altered sediments.

(2) Those which on similar grounds are certainly orthogneisses or sheared igneous rocks.

(3) A certain number of types which cannot yet with certainty be referred to either of the previous classes.

(1) Among the rock types which undoubtedly fall under the first heading are the thin bands of marble which are met with in two localities in the Glen Strath Farrar inlier. The first of these lies about half a mile west of Inchvuilt, where a band of marble, 6 or 7 ft. in thickness, is exposed, associated with graphite schist. The marble is coarsely crystalline, the individual grains of calcite average about an eighth of an inch across, and can easily be distinguished in the hand-specimen. In parts the marble is very pure, and consists almost entirely of calcite. The band cannot be traced for any distance. A very restricted outcrop of the same rock is also found in the lowest tributary of Allt Garbh-choire.

Another type whose sedimentary nature can hardly be questioned is a fine micaceous schist containing graphite. Graphite-schist occurs in two places in the Glen Strath Farrar inlier, in both instances close to the exposures of crystalline limestone above referred to. This association is an additional proof of the sedimentary origin of the graphite-schist. The rock associated with the second of the two outcrops of marble before referred to, is noteworthy from its resemblance to some of the graphite-schist found among the Lewisian Gneiss of Dornie (Sheet 71). There iron pyrites is irregularly disseminated throughout the graphite-schist, and in these portions there is often also a very small amount of gold. The resemblance to the Dornie rock is in general appearance, and in the presence of a certain amount of pyrites.

A third class of presumable sediments allied to the altered limestones includes the numerous bands of calc-silicate minerals which occur in every part of the complex. The most common mineral is tremolite; there is also malacolite (or diopside), epidote and some actinolite. A fair reason for supposing that these bands have been formed from sediments lies in the amount of lime and magnesia which, judging from the constituent minerals, must be contained in a bulk analysis of the material. This must have been in excess of the amount which would be likely to occur in an igneous rock, except under very special circumstances. Malacolite is on the whole less common than tremolite, but a band 3 ft. broad consisting almost entirely of this mineral occurs close to the margin of the inlier on the north-east side of Càrn Mòr. A band of rock consisting essentially of epidote, and 10 or 15 ft. in width, occurs about half a mile north by west from the summit of Creag Dhubh.

A remarkable and significant fact with regard to these paragneisses is the way in which they follow the margin of the inlier, and are also found along the margin of an "outlier" of Moine schist which occurs within the complex. The marble and graphite-schist in this particular area are thus met with only near such margins, and the same may be said of the broader bands of calc-silicate minerals, including the malacolite and epidote-rock before referred to. Thinner bands of calc-silicates occur, however, broadcast throughout the complex, and it is difficult to find any extensive exposure from which they are absent. Under the circumstances a mode of origin for these thinner bands similar to that assigned to the thicker masses cannot be assumed without further evidence.

(2) The orthogneisses, or altered igneous rocks, include the bands of hornblende-rock, with or without garnets, which form so marked a feature of the Lewisian complex of this region. To this group belong also the widely spread, sheared pegmatites, or acid igneous rocks with quartz and felspar.

The basic rocks occur in ellipsoidal knots, or, perhaps more commonly, as bands varying from a few inches to many yards in thickness. As a whole they are coarser than certain types of epidiorite occurring within the Moine schist. The individual crystals of hornblende can always be easily recognised, and are sometimes as much as a quarter of an inch in length; the hornblende is most commonly dark green or black in the hand-specimen. Two of the largest masses of hornblende-rock met with in this area occur on the north side of the river Farrar just above the bridge at Inchvuilt, and on the summit of a small hill (Tòrr nam Braonan) a little to the north of the last locality. These are both on the edge of the complex, and each measures fully a hundred yards across. In some of the bands dark biotite has more or less taken the place of the hornblende.

The pegmatites of this series can be easily distinguished from those in the surrounding Moine schist. The latter are generally little altered by movement, and show large crystals of felspar and mica as well as quartz. Those in the gneiss, on the other hand, have evidently been subjected to considerable shear. Some of the quartz crystals remain as rounded blebs, but the rest of the rock has been more or less completely granulitised and forms a fine-grained aggregate of quartz and felspar, with small parallel flakes of mica. This distinction is probably due to the fact that while the pegmatites in the Moine Series are either contemporaneous with, or later than, the movements which banded the series, those in the Lewisian Gneiss are earlier than these movements, and therefore affected by them. They must also be earlier than the deposition of the Moine sediments, as pegmatites in this state of shear are not met with among the latter. Whether, like the bands of hornblende-schist, they are earlier than the movements which originally banded the Lewisian rocks is a further question which will be discussed later. The evidence of their igneous origin rests partly on their rather sharply defined margins, and partly on the general similarity which they present, in spite of their metamorphosed character, to unsheared igneous rocks of a granitic type.

There are also certain bands which appear to be intermediate in

character between the hornblende-schists and the sheared pegmatites. In these, hornblende crystals occur in a more or less abundant matrix of felspar. In one place, also, three-quarters of a mile north by east from the Ordnance Survey cairn on Creag Dhubh, hornblende crystals of moderate size are found spearing a rock which resembles a fine micaceous granulite. It is uncertain, however, whether this last is an originally igneous rock.

(3) Among the types which cannot be so immediately referred either to the orthogneisses or the paragneisses, are the widely distributed calc-silicate bands to which reference has already been made. We may also notice a very quartzose rock approaching quartzite which has been met with at one point probably just within the border of the complex. This, from its composition, could hardly have been igneous, and as it does not seem likely to have been a quartz vein, it might almost have been included in the first of the three groups. Less certainty, however, attaches to various types of micaceous granulite which are widespread within the complex. The first of these types (A) is a more or less laminated, micaceous rock, which is very characteristic of the older gneiss of this area. A second type (B) is a fine micaceous granulite in which the mica (mainly biotite) is not arranged in laminæ but distributed regularly throughout the rock. This type is not so common as the last. A very abundant type is (C)—biotite-epidote-schist—which resembles (B) but with the addition of very numerous small grains of epidote.

The field evidence leads to the conclusion that these three types are probably paragneisses or altered sediments. They can be readily distinguished from rocks with about the same percentage of silica in the same series which are undoubtedly igneous. Thus the more quartzose, micaceous granulites bear no resemblance whatever to the sheared pegmatites already described. The remainder, if igneous, might be expected to have a composition intermediate between the pegmatites and the hornblende-schists, but they are altogether unlike the intermediate types which have already been classed as igneous. This difference might be explained on the supposition that the three types, (A), (B) and (C), were formed prior to the movements which banded the gneiss, but that the pegmatites were later than these movements, and therefore represent a lower stage of metamorphism.

The Lewisian Gneiss first makes its appearance within this area on the col which crosses the county boundary a little to the north of Sgùrr na Muice. Here it is seen to dip to the west beneath a band of pelitic gneiss somewhat resembling the laminated mica-schist (A) already described as forming part of the Lewisian complex, but differing from it in the entire absence of the hornblende-schists so characteristic of that complex. This pelitic gneiss occupies a band about 150 ft. in thickness at the base of the great cliff of siliceous Moine schist which forms the eastern face of Sgùrr na Muice, while underneath it lies the less resistant gneiss of the Lewisian complex, the difference in the rocks being emphasised by a marked change in the features of the mountain profile (see Plate IV.). The Lewisian Gneiss gradually increases in thickness to the south, and below it appears once more the siliceous Moine schist. South of Sgùrr na Muice both Lewisian and pelitic gneiss

East Face of Sgùrr na Muice, showing (I) Lewisian Gneiss underlying (II) Band of Pelitic Moine Gneiss, beneath (III) Massive Siliceous Moine Granulite.

are shifted eastwards by a fault on to the lower ground; and a little south of this point the pelitic gneiss dies out, bringing the Lewisian Gneiss into direct contact with siliceous Moine schist on both sides.

The Lewisian belt from this point preserves an approximate width of half a mile for about three miles to the south-west, and then has a considerable lateral extension. The westerly dip in the meanwhile becomes vertical, with a north-east strike, and finally the beds turn over and dip steeply to the south. Throughout this distance the western and north-western boundary is remarkably even, while the eastern one, in part at least, is very irregular. Along the eastern margin there are numerous bands of the undoubted paragneisses, while the adjacent rocks of the Moine Series exhibit, at various points, a structure very suggestive of a conglomerate. Both these distinctive features are absent on the western margin. It is possible that the latter may coincide with a zone of powerful shearing, something in fact almost equivalent to a thrust-plane, but formed at a greater depth. The difference may consist in the fact that there is no actual disruption along one particular plane, but enormous shearing throughout the thickness of a narrow band.

E. M. A.

CHAPTER VII.

PETROGRAPHY OF THE LEWISIAN INLIERS.

East of the Moine Thrust.

The rocks that occur in the Lewisian inliers of this Sheet differ in many important respects from the Moine schists and gneisses that surround them, so that neither in the field nor in the microscopic examination of sliced specimens are the two series likely to be confounded with one another. The peculiarities of the Lewisian rocks of the inliers, moreover, serve to approximate them to the unmoved Lewisian Gneiss that lies to the west of the Moine thrust-plane. Practically all their types can be met with in that region, while to the east of the Moine thrust these unusual rocks occur only in limited areas, intimately associated with one another in such a way as to suggest that they belong to one group and have a common origin. *

Within the inliers many kinds of rock may be found; in fact one of their striking features is their great diversity. Some of these are igneous gneisses (orthogneisses), while others are sedimentary, such as marbles and graphitic mica-schists. The Moine gneisses, on the other hand, are remarkably constant in their characters over a wide extent of the north-east of Scotland. They are essentially a group of sedimentary schists (paragneisses) ranging in composition from siliceous rocks (quartzites and quartz-schists), to pelitic mica-schists that must have been originally slightly quartzose shales. Taken as a whole the Moine Series has a somewhat monotonous character, as the rocks belong to a few classes which are repeated indefinitely over a great area. Intrusive into them are certain acid gneisses, such as the Inchbae augen-gneiss,† and many basic sills of amphibolite and hornblende-schist, but these are not difficult to distinguish by their microscopic characters from the rocks of similar composition that occur in the Lewisian inliers.

In structure the two groups present many contrasts, the Lewisian rocks being generally more coarsely crystalline and more irregularly foliated. In the Moine granulites the constituent minerals very commonly have rounded or not distinctly elongated forms, and the banding indicated by darker, more micaceous seams, and lighter bands, rich in quartz and felspar, is straight, narrow and

* A general account of the petrography of the Lewisian inliers among the Moine rocks was prepared by Dr. Flett, and appeared as an appendix to the "Summary of Progress for 1905," *Mem. Geol. Surv.*, 1906, p. 155.

† "The Geology of Ben Wyvis, Carn Chuinneag, Inchbae, etc.," *Mem. Geol. Survey*, 1912, p. 46.

frequently repeated. The scattered flakes of mica have a parallel orientation, but tend to occur mixed up with the quartz and seldom form discrete folia. The acid gneisses of the Lewisian are coarser, more flaky, and their foliation tends to be interrupted or discontinuous. The Moine mica-schists are often highly crystalline, with large plates of muscovite and biotite, and this type of rock occurs also in the Lewisian inliers, but generally contains much dark graphite, and sometimes andalusite and kyanite.

Hornblende-gneisses. — Probably the commonest rocks of the Lewisian inliers are the hornblende-gneisses; they are almost as distinctive of this series as the banded granulitic gneisses are of the Moine rocks. Microscopic sections have been made of hornblende-gneisses from the Scardroy, Allt Riabhachain and Gleann Fhiodhaig inliers. No two of them are strictly alike, yet they are all very distinct from the Moine rocks of this Sheet and the Sheets to the north and east of it. They contain quartz, various felspars (including orthoclase, albite, oligoclase and andesine), and much dark green, highly pleochroic hornblende.

Among the Lewisian hornblende-gneisses we may distinguish a variety of types that differ somewhat in their microscopic structure, and still more in the relative abundance of the component minerals. Some are rather pale-coloured rocks with much quartz and felspar (Scardroy 12395, 12398). In these there is often a good deal of biotite, so that they afford a transition between the biotite-gneisses and the hornblende-gneisses. Their principal felspars are orthoclase and albite, but microcline and micropegmatite occur sometimes. In this group epidote is often a very common mineral (12398), and its irregular crystals may contain small cores of brown orthite (13014, Liathanach). Sphene also is rather frequent, but garnet apparently does not occur.

There are, on the other hand, dark basic types of hornblende-gneiss which might well be described as amphibolites. Their principal mineral is hornblende, usually very dark green in thin sections, and sometimes brownish. Quartz is often fairly abundant in these rocks (11633 Garbh-uisge). Occasionally alkali-felspar is present in considerable amount (11382 Creag Sgiathan) while in other specimens there is a good deal of brown biotite (11654 Allt Toll a' Mhuic). Garnet, however, is the principal accessory mineral, and often occurs in numerous crystals which may be a quarter of an inch in diameter, and the rocks of this type may be regarded as garnet-amphibolites. In some of them the hornblende is brown (11637 Allt Uchd Rodha), and there is a fair quantity of biotite, quartz, sphene and rutile. More commonly the hornblende is green (11383 Creag Sgiathan), and there is a certain amount of felspar (albite and oligoclase). The garnet seems to fill the *rôle* of the lime felspar commonly found in basic igneous rocks. In this connection it is interesting to note that epidote is comparatively rare in these rocks, but sphene is rather abundant. The large garnets are studded with inclusions of all the other minerals (11652 Inchvuilt).

These rocks often approach very closely to the garnetiferous hornblende-schists that form sills in the Moine Series. They consist of the same minerals, in very much the same proportions, but in the Moine amphibolites the hornblende is very constantly olive-

green to brown, and zoisite and epidote are rather frequent (12649 Allt a' Chreagain Bhuidhe). Some of these rocks also contain felspars of the andesine-labradorite series (11655 Allt Uchd Rodha, Glen Strath Farrar).

Pyroxene-Gneisses.—The pyroxene-gneisses are probably the most characteristic of all the orthogneisses of the Lewisian complex. They have an extensive development in the areas west of the Moine thrust-plane, and that they appear also in the inliers among the Moine rocks is especially significant.

No gneisses of this type are known to occur as integral members of the Moine Series. Examples have been sliced for microscopic examination from Allt Garbh-choire (13288), and Allt Riabhachain (12411–2). In all of them pyroxene is present, usually of a pale green variety, but sometimes nearly colourless (13288). It never shows crystal outlines, and is always accompanied by hornblende which may surround it in such a manner as to suggest that the amphibole may be in part secondary after the pyroxene (12412). Epidote may be exceedingly abundant in these rocks (12411) and gives them a yellow or pale-green colour in the hand-specimens. Sphene occurs also, and there is much quartz and felspar, but garnet does not appear in the rocks sliced. The felspar is often orthoclase and albite, with lower refractive indexes than those of quartz.

Eclogites.—These seem to bear the same relation to the pyroxene-gneisses as the garnet-amphibolites have to the hornblende-gneisses. They contain many large, irregular garnets filled with inclusions of the other minerals. Pale green augite (omphacite) is abundant, but differs from that of the pyroxene-gneisses in being traversed by small, dark, rod-shaped bodies closely resembling, and no doubt analogous to, the schiller-inclusions of the diallage of gabbros. This feature, we may remark, is very characteristic of the augite of certain pyroxene-gneisses in the Scourie district that have been described by Dr. Teall.* Green hornblende, in part fringing the augite but also as separate crystals, is quite common, and there is much quartz and iron oxides. Sometimes the hornblende is pale-green at its centre, and may then be paramorphic after augite. Felspar is apparently absent, but the rock may contain a good deal of apatite. Only one member of this group has been examined microscopically (12421); it comes from An Cruachan.†

Ultra-basic Rocks.—No feature is more characteristic of the Lewisian Gneiss in its typical development in the west of Sutherlandshire than the large number of basic and ultra-basic dykes that intersect it. In the Lewisian of the inliers no such dykes are known, though this does not exclude their occurrence, as they may have been so distorted and dragged out by a second epoch of earth movement that they can no longer be recognised as having a distinct identity. It is interesting to observe, however, that among the gneisses of the inliers there are soft, pale chlorite-tremolite-schists which are undoubtedly derived from the metamorphism of peridotites. Rocks of this type occur north-north-west of Carnoch (11378–80)

* "The Geological Structure of the North-West Highlands of Scotland," *Mem. Geol. Survey*, 1907, p. 53.

† For a photomicrograph of this eclogite, see "Summary of Progress for 1905," *Mem. Geol. Surv.*, 1906, plate iv. fig. 2.

and, in one of these, relics of the original olivine may be seen,* weathering in the usual way to serpentine. Their other components are magnetite, carbonates, white aggregates of scaly talc, pale rods of tremolite and little plates of chlorite that have a fairly strong dichroism (yellow to green), a double refraction similar to that of felspar and well-marked polysynthetic twinning. These rocks are well foliated and show no trace of original igneous structure. In some slides this chlorite is almost colourless; it is a variety of clinochlore. Ultra-basic rocks are not absolutely confined to the Lewisian, since there is an interesting group of peridotites (scyelites, etc.), among the Moine gneisses in the district to the north-east of this Sheet.†

Biotite-gneisses.—In the Lewisian inliers these are next in abundance to the hornblende-gneisses, from which, as already stated, they cannot be divided by a hard-and-fast line, for some of the biotite-gneisses contain a small amount of amphibole (12428 An Leth-chreag). Many of these rocks are very rich in felspar (orthoclase, albite and oligoclase). Muscovite is not very common, but appears sometimes (12548 Allt Toll a' Mhuic). Micropegmatite, of the myrmekite type, is rather scarce (12547 Creag Dhubh). A special feature of these rocks (and of some of the hornblende-gneisses), is their richness in epidote. The micro-sections are full of this mineral in irregular yellow grains: very often they have cores of brown or orange orthite, easily recognised by its dark colour and different optic orientation, though the two minerals are in parallel growth. It has been pointed out by Dr. Peach that the eroded surface of the Lewisian gneisses below the Torridon Sandstone is often highly epidotic, and there is a strong probability that the Lewisian floor on which the Moine sediments were laid down had been similarly affected. At any rate these epidotic biotite-gneisses adhere closely to the junction of the two formations, for they are very distinct in composition and in microscopic structure from the beds of zoisite-hornblende-gneiss that occur as integral parts of the Moine Series.

Between the biotite-gneisses of the Lewisian and those of the Moines, as already remarked, there are not a few points of distinction. As a rule the Lewisian rocks are coarser, less uniform in composition and in foliation; the uniform granoblastic texture so distinctive of the Moine psammitic gneisses is rarely approached by the Lewisian rocks, and the latter, also, not unfrequently show well-marked cataclastic effects as if they had been irregularly crushed or broken by a later series of movements than those that impressed on them their high crystallisation and original foliation.

Marbles, etc.—We pass next to the consideration of those rocks of the Lewisian inliers which are recognisably of sedimentary origin. Among these two types prevail—the limestones and the graphitic mica-schists. Both of them are strikingly different from the Moine rocks that surround them. In the latter formation mica-schists have a large development and cover immense areas; in fact the shales of the Moine Series, now converted into various kinds of mica-schist, occupy more of the surface of Scotland than those of any other of

* "Summary of Progress for 1905," *Mem. Geol. Survey*, 1906, plate iv. fig. 3.

† "The Geology of Ben Wyvis, Carn Chuinneag, etc.," *Mem. Geol. Survey*, 1912, p. 126.

the geological systems. Yet graphitic schists are very rare in this group, and have nowhere been found in typical development. Still more distinctive are the Lewisian limestones, for among the Moines highly calcareous rocks are found only in a few localities, while among the sediments of the inliers they take a very important place. In both respects the rocks of the inliers have a strongly Lewisian facies, recalling the limestones and mica-schists of Tiree, Glenelg and Loch Maree.

The calcareous rocks are rather coarsely crystalline and include marbles, calc-silicate-rocks and calc-mica-schists. The marbles are rarely quite pure; they contain variable proportions of silicates such as mica, tremolite, diopside and scapolite. A pale mica is perhaps most widespread; it is almost colourless and hardly at all pleochroic in thin section, and belongs presumably to phlogopite. Tremolite also occurs frequently in small white or transparent prisms that have imperfect crystal faces. A colourless or pale-green augite (malacolite or diopside) is very abundant in many specimens. Its grains are irregular or somewhat rounded, and the prismatic cleavage is the only one that is well developed. The pyroxene is sometimes fringed with a greenish variety of amphibole that seems to be of secondary origin. Only one slide shows forsterite in rounded granules weathering to pale serpentine and partly replaced by infiltrated calcite. Among the other accessory minerals sphene is fairly common (usually of a pale brown variety), and shows occasionally an approach to idiomorphism. Spinel has not been observed in any of the microscopic slides, and garnet also appears to be absent. Epidote is not common in those specimens that are rich in calcite, though with diopside it occurs in great quantity in certain bands or nodules, associated with them. Quartz and alkali-felspars also are seldom found in the purer marbles.

Perhaps the most characteristic mineral of the limestone of the Lewisian inliers is scapolite. It is exceedingly common in these rocks (12393 Allt Coire Dubh) (12647 Allt a' Chreagain Bhuidhe) (13287, 13289 Allt Garbh-choire), and is often fresh though at times decomposed into fibrous secondary products. This mineral occurs in certain Lewisian rocks * and is well known in the Tiree marble, but its abundance in the inliers east of the Moine thrust-plane is a special feature of the rocks under consideration. It has always a strong birefringence, and appears to belong to the scapolites of the mizzonite and meionite groups which are comparatively rich in lime. The scapolite forms only small grains seldom visible to the unaided eye and shows little trace of idiomorphism.†

Where the original limestones have been highly impure the metamorphism has produced rocks that may be described as malacolite-rocks, epidote-pyroxene-rocks, and scapolite-pyroxene-rocks. Some of these contain a little alkali-felspar and quartz, but their minerals have the same characters as in the purer marbles above described.

Epidosites—The epidosites of the Lewisian inliers have apparently

* J. S. Flett, "The Scapolite-bearing Rocks of Scotland," in "Summary of Progress for 1906," *Mem. Geol. Survey*, 1907, p. 116.

† "Summary of Progress for 1905," *Mem. Geol. Survey*, 1906, plate iv. fig. 4.

no large development, and are probably of more than one origin. Some of them contain diopside and seem to be contact-altered, impure limestones, but epidote is frequently also in the hornblende-gneisses and biotite-gneisses, and certain specimens may represent segregations that have arisen in these rocks in course of the metamorphism.

The general impression produced by a study of the marbles and calc-silicate-rocks is that they must have undergone thermal alteration at some period of their history. All of their accessory minerals occur in the limestones of the eastern and southern Highlands, south of the Great Glen, but only where these are in the vicinity of intrusive rocks which have altered them. The same character is reflected even more strongly by the argillaceous schists of the Lewisian inliers.

Mica-schists.—In the An Cruachan inlier graphitic mica-schists occur (12422) that contain crystals of pale andalusite, irregular in form and free from inclusions.* This schist appears to be cut by thin granite veins that intersect its foliation obliquely. Another specimen, collected 1100 yds. west of the summit of Sgùrr Fhuarthuill, is a garnetiferous biotite-schist with large crystals of oligoclase (12552). Much kyanite occurs in this rock both in granules and in long needles embedded in the oligoclase porphyroblasts. Kyanite is well known to be a mineral indicating contact action around the intrusive gneisses of the Scottish Highlands.

It has been already pointed out† that the presence of minerals such as kyanite and andalusite in the graphitic schists of the Lewisian inliers, while the Moine mica-schists adjacent to the Lewisian gneisses show no similar phenomena, is good evidence that these two sets of argillaceous rocks belong to two quite different systems, one being older than the Lewisian orthogneisses while the other is of subsequent date.

Enough has been said to indicate how distinct in character are the rocks of the Lewisian inliers from the Moine gneisses that surround them. The petrographical evidence alone, if the field evidence were entirely obscure, would show that the inliers are Lewisian rocks and cannot be assigned to the Moine Series. The limestones, graphitic schists and kyanite-schists, are a close parallel to the sedimentary rocks of Loch Maree; the abundance of hornblende-gneisses and pyroxene-gneisses recalls the Lewisian orthogneisses between Loch Broom and Scourie; but pyroxene-gneisses also occur in the Loch Maree district.‡ In some respects, however, the rocks of the inliers do not exactly resemble any part of the Lewisian Gneiss west of the Moine thrust-plane. The abundance of epidote and orthite, the presence of andalusite in the mica-schists, the scapolite-bearing limestones, the forsterite in the marbles, the frequent eclogites, mark out the Lewisian rocks of the inliers in central and western Ross-shire. Practically all these distinctive

* "Summary of Progress for 1905," *Mem. Geol. Survey*, 1906, plate iv. fig. 6.

† J. S. Flett, in "Summary of Progress for 1905," *Mem. Geol. Survey*, 1906, p. 166.

‡ "The Geological Structure of the North-West Highlands of Scotland," *Mem. Geol. Survey*, 1907, pp. 82 and 195.

features are shown, however, by the Lewisian orthogneisses and sedimentary schists that have been described from the district of Glenelg by Mr. Clough*. The Glenelg mass is east of the Moine thrust-plane, and may fitly be regarded as the greatest of the Lewisian inliers. These facts show that, just as every tract of Lewisian rocks in the north-west of Scotland hitherto described possesses individual peculiarities, the Lewisian gneiss that extended below the Moine rocks to the east and was driven westwards by the post-Cambrian movements which gave rise to the great thrusts, had a distinctive facies of its own.

In structure, on the other hand, the rocks that have been described in this chapter depart somewhat from the normal Lewisian type. Many of the gneisses and the mica-schists are very like those of the western part of the county, but none of the basic igneous rocks has preserved its igneous structures. There are no dolerites or normal peridotites; the limestones, also, are often much sheared, and in the gneisses cataclastic effects are very prevalent. We shall find no difficulty in ascribing these features to the influence of a second set of earth-movements that cast the Lewisian floor and the Moine sediments resting on it into a complicated system of folds, perhaps the same as converted the arkoses and sandy shales of the Moines into granulitic gneisses and highly crystalline mica-schists.

J. S. F.

* "The Geology of Glenelg, Lochalsh, etc.," *Mem. Geol. Survey*, 1910, p. 16.

CHAPTER VIII.

THE MOINE SERIES.

i. Area between the Moine Thrust and a Line drawn from the River Ling to the Head of Glen Docherty.

Attention will first be directed to the tract between Glen Carron and the river Ling, which, by means of the lithological characters of the Moine schists, may be further subdivided into—(1) a western subdistrict, situated on both sides of Loch Carron west of Attadale and the alluvium of the river Carron, and (2) an eastern subdistrict extending beyond these boundaries to the river Ling.

In the western subdistrict both psammitic and pelitic rocks are represented. In that part of it situated to the north of Loch Carron the grade of metamorphism is comparatively low. The pelitic rocks consist of slates and phyllites. The constituents of the psammitic rocks have, in many cases, not been wholly granulitised as shown in some coarse-grained, pebbly arkoses associated with dark slates and phyllites in the Kirkton Burn, and in some calcareous grits interleaved in phyllites on the shore opposite the inn at Lochcarron. The dominant strata, however, are fine-grained, platy quartzose flags in which the grains have been more or less completely granulitised. Muscovite is the chief mica, but small crystals of biotite also occur.

Just above the outcrop of the Moine thrust-plane where it is exposed to the west of Lochcarron village the granulitic flagstones are seen to be much crumpled, crushed and even comminuted. In the two islands, Sgeir Fhada and Sgeir Chreagach, in Loch Carron, there are exposures of granulitic flagstones containing blue quartz and felspar peripherally granulitised. On the east side of the loch in the narrow strip of Moine rocks along the shore, lying in a fold of Lewisian Gneiss, the grade of metamorphism is somewhat more pronounced. At the junction with the Lewisian rocks there occurs in places a band of biotite-actinolite-schist, enclosing elongated masses of granulitised epidotic gneiss, hornblende-schist and grains of white and purple stained granulitic quartz—features suggestive of an altered basement conglomerate. Next to this band there is a considerable thickness of muscovite-biotite-schist with garnets and wisps of actinolite along certain layers, which is succeeded by phyllites and biotite-schists with zones of calcareous rock and even limestone and marble. Beyond this pelitic zone, and occupying the core of a recumbent fold, we find flaggy, granulitic, quartzose schists with thin micaceous partings like those at Loch Carron. All these types are traversed by quartzo-felspathic veins usually at an acute

angle to the divisional planes of the schists, the constituents of the veins being for the most part streaked out and granulitised.

In the eastern subdistrict there is evidence of increasing metamorphism as the rocks are followed from west to east. The contact between the Moine schists and Lewisian Gneiss is only seen on the west side of this subdistrict, south from the mouth of the Attadale River. At the base of the series we there find pelitic schists similar to those just described, with a rock that may represent a conglomerate at the junction. The pelitic belt is followed eastwards by a zone of granulitic quartzose flagstones. Up to this point the schists present a grade of metamorphism similar to that in the synclinal fold of Loch Carron.

Beyond the flagstones we find massive granulites containing muscovite and biotite, with occasional alternations of muscovite-biotite-schist. This belt is over a mile in width and extends from the southern edge of the map to the river Carron at Craig. Eastwards this belt is followed by massive siliceous and felspathic granulites with few or no pelitic intercalations. The latter have evidently been derived from coarse arkoses, and, notwithstanding the intense movement which they have undergone, some of the larger felspar pebbles have not been wholly granulitised. The biotite is definitely orientated along the cleavage planes which dip persistently to the south-east irrespective of the highly involved folding. South of an east-and-west line drawn from Attadale House to the river Ling these massive granulites occupy the remaining part of the area. North of that line, however, they enclose in an isoclinal fold extending north-east for a distance of about four miles, a narrow belt, about half a mile wide, of fine-grained biotite-granulites, which in some bands are studded with minute concretionary nodules of quartzo-felspathic material. A thin zone of platy quartz-granulite, with divisional planes covered with muscovite and blotched with aggregates of magnetite elongated in the direction of movement, intervenes between these biotite-granulites and the massive coarse granulites on either side. Such an arrangement affords presumptive evidence that the fine-grained biotite-schists occupy the core of a great recumbent synclinal fold.

The increasing metamorphism observable in the schists when followed towards the east is chiefly shown by the coarser crystallisation of the materials of each successive zone, but more especially by the veins traversing the gneiss. While in the western area these veins are composed mainly of quartz, some felspar, and vermicular chlorite which have been generally affected by the movements, in the eastern area, on the other hand, along the valley of the Ling to Loch Sgamhain at the head of Glen Carron, they consist of quartzo-felspathic material or muscovite-pegmatites, the muscovite appearing in large crystals which show no evidence of movement.

B. N. P.

In the triangular tract of Moine schists lying between Glen Carron and Glen Docherty there is no marked increase in the grade of metamorphism till we reach Càrn Beag and Beinn na Feusaige from 3 to 4 miles east from the Moine displacement.

Immediately beneath the Moine thrust to the north and south of Loch Coulin, there is an important belt of strata about a quarter

of a mile in width that presents characters intermediate in structure between the deformed Torridonian sediments to the west and the true crystalline schists of the Moine Series to the east. The petrological characters of these rocks have already been described in the section dealing with the tectonics of the post-Cambrian movements (p. 21).

Above the Moine disruption a thin zone of green phyllitic schist is exposed near the Kinlochewe Hotel and in the Kinlochewe River opposite Cromasag, which resembles the "oyster shell" rock or "frilled schist" of Eireboll. It appears at intervals above this plane along the line to Achnashellach station. Next in order comes a belt, from 2 to 3 miles in width, of flaggy and sometimes massive quartzose schists with typical granulitic structure. Near the Moine thrust the divisional planes are finely striped, and the minerals are orientated in the direction of the post-Cambrian movements, like those in the deformed Torridonian rocks in the Coulin Forest. Occasionally bands of mica-schist varying in thickness from a few inches to several feet are interleaved in this group, but these are not a characteristic feature. This uniform quartzose, granulitic series occupies the high plateau of Càrn Breac (2220 ft.) and Féith an Leothaid, south of Glen Docherty. A band of quartz-magnetite-schist, intercalated in this group, was detected on the north-east shoulder of Càrn Breac at the level of 2000 ft. A prominent zone of augen-schist, also occurring in this group, is well displayed on the crags on the south side of Glen Docherty, about a mile and a half up the glen from Kinlochewe Hotel, and on the plateau north of Lochain Féith an Leothaid. The matrix is a typical granulitic schist of Moine type in which round "eyes" of felspar appear in marked contrast with the lenticular or compressed forms assumed by felspars in zones of shearing. The abundance of quartz-veins in this group is a noteworthy feature. They are well developed on the south and east slopes of Càrn Breac, about the 2000-ft. level, where they range from 1 to 12 in. in thickness. In all observed cases these segregations are granulitised. Sometimes they are arranged along the strike of the schists, that is, N.N.E. and S.S.W., or slightly oblique to it. In other cases, owing to the folding of the Moine schists along west-north-west and east-south-east axial planes, they appear as quartz-rods trending more or less in that direction.

The quartzose granulitic group is succeeded eastwards by alternations of psammitic and pelitic schists forming a belt about a mile in width that crosses the plateau from the upper part of Glen Carron to the head of Loch a' Chroisg. The best section of these rocks is to be found in Allt Coire Crubaidh, which flows into Loch Sgamhain at the head of Glen Carron. In the quartzose schists minute biotite is associated with the muscovite, and in the pelitic bands biotite is abundantly developed.

Eastwards, we find on Càrn Beag and Beinn na Feusaige well-banded biotite-gneisses indicating a high grade of metamorphism. This stage of mineralisation is coincident with the introduction of quartzo-felspathic material, sometimes arranged in folia more or less parallel with the psammitic and pelitic layers, sometimes crossing the foliation and isolating portions of the Moine gneiss.

In the latter case the material is composed of quartz, felspar and biotite, and behaves like a granitic intrusion. In association with this granitic material we find veins of microcline-muscovite-pegmatite, which are not granulitised and show no trace of deformation so far as the observations in that region have gone.

The biotite-gneisses of Càrn Beag are followed on the east side by the zone of garnetiferous muscovite-biotite-schist that has been traced southwards to Moruisg and northwards to Creagan nan Laogh. J. H.

ii. Monar Area.

The three main zones of the Moine Series (see Chapter V, p. 26) can be recognised in the Monar district, and their order of succession is clearly established by the sections exposed on, and in the neighbourhood of, Beinn Dronaig. A broad band of pelitic gneiss (b^2) has been traced from Sgùrr Mòr Fannich, in Sheet 92, for a distance of 27 miles to its southern termination on Càrn na Seanlùibe, about 2 miles south of the summit of Beinn Dronaig.

This band, which throughout its course is bounded on either side by rocks of siliceous Moine type, is here abruptly truncated by a line at right angles to the general strike. (See Fig. 5, p. 59).

Along this line the pelitic gneiss (b^2) inosculates with the overlying siliceous schist, the nearly vertical folds of the former pitching beneath the latter in a south-east direction and giving rise to a jagged boundary line.

The cause of this phenomenon is found in a sudden change in the direction and character of the folding which affects the beds in the immediate vicinity. North of Beinn Dronaig the rocks of this belt of pelitic gneiss are isoclinally overfolded in a general north-west direction, the limbs of the folds lying at low angles and dipping to the south-east.

Along a line extending southward from the summit of Beinn Dronaig as far as and beyond the southern margin of this Sheet the country is, however, traversed by belts of vertical folding, the axes of plication striking N.N.W. and S.S.E., *i.e.*, nearly at right angles to the axes of the gently inclined overfolds met with in the rocks to the north-west of the belt of vertical folding.

These vertical isoclinal folds pitch S.S.E. nearly in the same direction as the dip of the limbs of the overfolds. The accumulated effect of this vertical folding causes the pelitic gneiss to plunge suddenly to a lower level along this boundary line, which terminates the belt of pelitic gneiss in a manner that simulates the effect of a monoclinal fold. The belt of vertical folding has been followed in the siliceous schists to the south for a distance of over a mile and passes into the adjoining map.

For a short distance to the west of this area of vertical folding the strike of the rocks swings round in a direction almost parallel to the strike of the vertical folds; the plication is of the gently overfolded type, and a distinct mullion-structure, parallel with the strike of the vertical folds, is developed.

The mullion-structure also pitches in the same direction as the vertical folds, and is evidently connected in its origin with the vertically folded belt, and would appear to be due to the same

movement acting with a less degree of force. Where the pelitic gneiss enters into the vertically folded belt, the long, drawn-out eyes of pegmatite that generally characterise these rocks are much more abundant than in those areas where the ordinary isoclinal overfolding occurs.

This vertically folded structure is emphasised by the behaviour of a band of siliceous schist which has been traced for several miles from the north-east within the outcrop of the pelitic gneiss. On the summit of Beinn Dronaig this siliceous band becomes involved in the belt of vertical folding and plunges steeply beneath the overlying pelitic gneiss. With this siliceous rock, which is referred to the lowest zone of the Moine Series (b^1), are associated several small exposures of Lewisian Gneiss which thus form the very core of the anticline.

The continuity of the boundary line between the pelitic gneiss and the siliceous Moine schist round the southern extremity of the crop of the pelitic gneiss belt proves that we have to deal with the same zone of siliceous schist on either side of, and around the extremity of, this pelitic belt. The truncated band of siliceous schist on Beinn Dronaig, within the pelitic outcrop, surrounds inliers of Lewisian Gneiss which do not appear within the pelitic rocks; this of itself is strong evidence that this siliceous schist underlies the pelitic gneiss.

The folds of the lower siliceous schist, moreover, pitch beneath the pelitic rocks, while the folds of the latter pitch in turn beneath the outer band of siliceous schist that surrounds the pelitic belt, and must in consequence overlie it.

The order of succession of the rocks of the Moine Series in this area is therefore as follows:—

3. Upper siliceous Moine schists.
2. Pelitic gneiss.
1. Lower siliceous Moine schists: a sequence which accords with the arrangement and grouping of the rocks found in the Attadale syncline which immediately succeeds the Beinn Dronaig anticline on its western side.

This peculiar belt of vertical folding not only affords a means of establishing the order of succession in the rocks, but is also of interest from the point of view of its structural evolution.

Belts of folding having a different orientation from the normal direction of overfolding of the surrounding country have been observed in other parts of the Moine area, and, together with the usual overfolding, have been referred to as the "double system of folding" in the Moine schists.*

The example found at Beinn Dronaig is, however, peculiar in involving three zones of the Moine Series as well as the underlying Lewisian Gneiss. The evidence shows that the lower members of this series laid bare in the core of the anticline along this line of vertical folding disappear beneath the surface, their places along the strike of the overfolding being abruptly taken by members higher in the series, the displacement being monoclinal in character.

There are difficulties in explaining this type of structure by a

* "The Geological Structure of the North-West Highlands," *Mem. Geol. Survey*, 1907, ch. xi., p. 601.

later system of vertical folding imposed upon an earlier system of overfolding.

On the north-east side of the belt of vertical folding the strike of the gently overfolded rocks continues right up to the line where the abrupt change in the type of folding takes place. On the south-west side there is, on the contrary, a divergence in the strike of the overfolds, which swing round from northeast-southwest to nearly north-and-south, this change being continued for a mile or more beyond the vertically folded belt before the former strike is resumed; for part of this distance the rocks show the mullion-structure noticed above.

On the north-east side, therefore, the change in the character of the folding is sudden, but on the south-west side more gradual. Had the vertical folding been imposed secondarily on the overfolding, we should expect the change to be symmetrical and abrupt on either side of the vertically folded belt. The longer axis of the vertically folded belt is, moreover, not parallel to the direction of the axis of folding, nor is it quite at right angles to the strike of the overfolds to the north-east, but can be traced in a direction due north-and-south as a succession of parallel folds with a N.N.W.-S.S.E. strike and pitching steeply to the S.S.E.

The fact that the belt of folding does not extend into the ground north of Beinn Dronaig, where the strike of the rocks gradually swings round, is also of significance. There is also no evidence of two foliations either within or in the neighbourhood of the belt, and it seems more probable that the two systems of folds are synchronous and due to the same movement.

The vertical plication may have been produced by a differential overfolding movement. During the forward overriding movement the portion of the overfold on one side of the line of drag would remain behind and at a lower level than that on the other. Along the line of drag the beds would be vertically folded, owing to the rocks having to occupy less space in a direction at right angles to the line of forward motion. An overriding of certain sections and a dragging behind of others would thus be necessitated, in order that the line of advance might occupy less space. The rocks included within the pelitic band on the north-east side of the vertically folded belt must on the south-west side plunge beneath the surface. They would in this case have dragged behind during an adjustment in the general forward movement.

Lower Siliceous Schists (b^1).—The rocks of this zone exposed on Beinn Dronaig are somewhat massive, pale in colour and composed of quartz and felspar, with rather large flakes of a pale greenish mica. They also contain numerous scattered, small, idiomorphic garnets of a clear port-wine colour.

The outcrop of these schists has been traced from the summit of Beinn Dronaig northwards through the West Monar Forest as far as Sgùrr Choinnich, and forms a narrow band in the core of the Beinn Dronaig anticline.

A second outcrop of a rock of exactly similar character is infolded with the pelitic rocks on the north shoulder of Sgùrr na Lapaich and presumably belongs to the same zone, but its structural relations with the pelitic gneiss are not clear.

The Pelitic Gneiss (b^2).—This zone occupies two separate outcrops in the Monar area.

1. A broad belt which extends northward from Càrn na Seanlùibe along the denuded Beinn Dronaig anticline and across the West Monar Forest. Except at its southern extremity, where it terminates in the line of vertical folding already referred to, the rocks are arranged in a system of gently inclined overfolds which dip to the south at angles of about 30°. In the northern part of the West Monar Forest the dip is at higher angles and more easterly in direction.

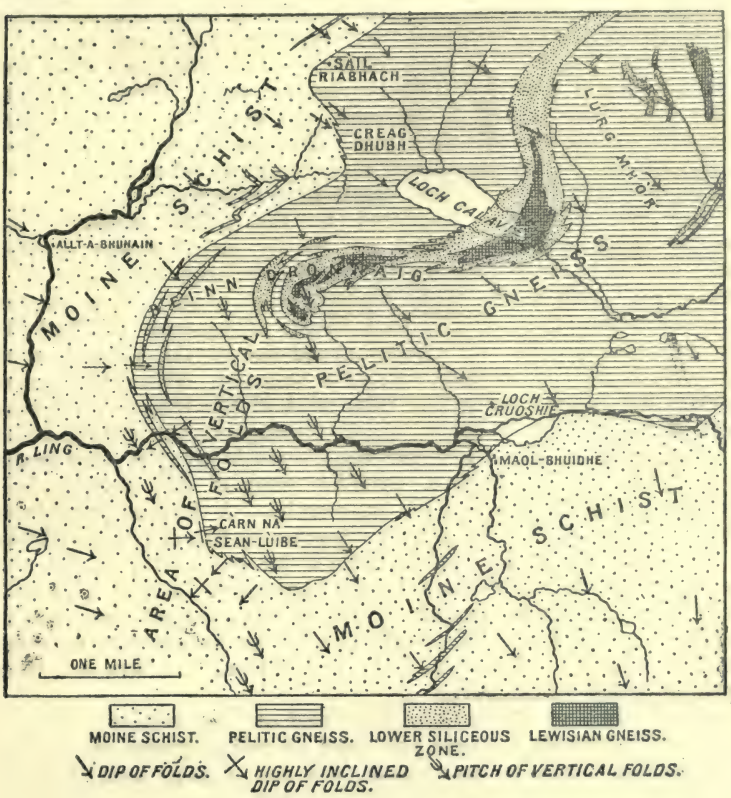

FIG. 5.—Map of the Beinn Dronaig Area.

2. The second outcrop of the pelitic gneiss lies to the east of the Strathconon fault, which truncates its western end on the lower slopes of An Riabhachan. The mountain forms of An Riabhachan and Sgùrr na Lapaich are chiefly carved out of this mass of gneiss.

The rocks are overfolded to the north and N.N.W., the general strike being parallel to the trend of the An Riabhachan ridge.

The southern margin of this outcrop lies outside the Sheet, and has not yet been mapped. The northern margin is very irregular, but is roughly parallel with the lower slopes of the mountain ridge. The pelitic rocks are in contact for 1½ miles to the west with the

Lewisian inlier that occupies the slopes between An Riabhachan and Meallan Buidhe, and also with the Lewisian Gneiss on the N.E. shoulder of Sgùrr na Lapaich. To the west of Meall Garbh the pelitic gneiss, however, succeeds the upper siliceous zone of the Moine Series, and a long strip of the former rock, surrounded by siliceous schists, extends from Meall Garbh along the course of the Uisge Misgeach.

The evidence for the correlation of this pelitic gneiss of An Riabhachan with that of the Beinn Dronaig anticline is not conclusive, but from its relations to the Lewisian inliers and to the siliceous Moine schist of the Monar syncline, there is good reason for the belief that the two pelitic outcrops are on the same horizon.

The rocks included in these outcrops are similar in nature and show very little variation from the normal type. Black and white micas both bulk largely in the rock, and strings and lenticles of pegmatite are common, as elsewhere. Garnets are abundant in most of the bands and are sometimes idiomorphic, sometimes broken and in irregular masses. No zoisite bands were detected.

The surface-features produced by the pelitic gneiss in the country south of Loch Calavie are hardly characteristic of that rock, the Beinn Dronaig region having suffered glaciation to a late period. But in the West Monar Forest, where the mountains included within the belt rise to a height of upwards of 3000 ft., the magnificent cliffs and corries carved out of the dark massive mica-schist are conspicuous even at a distance. The pelitic gneiss extends for 3 miles along the ridge west of Strathmore, stretching from Meall Mòr to Bidein a' Choire Sheasgaich, the outcrop being of great width at this point and the overfolds lying at very gentle angles. Along this ridge it exhibits many of the characteristic features of the pelitic gneiss topography. A line of precipitous cliffs facing north and broken at intervals by fine cirques overlooks Strathmore. The summit of the ridge is for the most part flat and debris-strewn, but on Bidein a' Choire Sheasgaich the rock rises into a sharp peak, 3100 ft. in height, which affords a magnificent view to the west. Part of the ridge forms a knife edge, where a corrie facing south at the head of the Allt a' Ghraigh-fhear has been cut back close up to the waterparting.

Fine cliffs and corries are also found on the northern face of Sgùrr a' Chaorachain, where the band of pelitic gneiss crosses the waterparting north of Strathmore, but the outcrop here is much narrower, owing to the steeper dip, and the top of the ridge more irregular.

The An Riabhachan ridge forms a succession of narrow debris-strewn tops at elevations considerably over 3000 ft. At the western end of the mountain-crest the cutting-back of opposing cirques on either side of the waterparting has in places reduced the ridge to a knife edge for some distance. The scenery of this ridge reproduces on an even grander scale the mountain-features produced by the pelitic gneiss in the West Monar Forest and, at its eastern end, the fine mountain-peak of Sgùrr na Lapaich bears a striking resemblance to the pinnacle of Bidein a' Choire Sheasgaich, but is of greater altitude, the summit cairn, 3773 ft., being the highest point within the map.

The narrow crest of Riabhachan is covered with the frost-weathered debris so characteristic of these elevated ridges. On the steeper slopes the weathered material moves downwards in the form of rain-wash mixed with some scree material. The lower slopes are very green, owing to the predominance of grass over heather. The mica-schist disintegrates gradually under the action of the weather into a fine earthy debris, more retentive of water and richer in chemical food-material than the coarse debris which results from disintegration of the more siliceous rocks. On the elevated plateaux the earthy debris is subjected to the sorting action of violent winds, and the coarser fragments alone occupy the surface, which is in consequence very porous and supports a vegetation of an Alpine desert-type. On the slopes of the mountain the finer material collects as rain-wash where the gradient is not too steep, and produces a fine grassy pasture.

Upper Siliceous Schists. — The rocks of this zone have been traced round the underlying pelitic gneiss of the Beinn Dronaig anticline. On the farther side of the Strathconon wrench rocks of exactly similar character occupy the ground north of the pelitic gneiss of An Riabhachan. The extent of displacement caused by the wrench is unknown, but the character of the siliceous rocks, and their relations to the Lewisian inliers on either side of the fault, are the same.

The schists of the upper group are as a whole strongly quartzo-felspathic, with subordinate and scattered micas. They are more or less massive, and often distinctly show the original planes of bedding. Original clastic grains of quartz and felspar are common, and in the region south-west of Beinn Dronaig the rock is sometimes even pebbly.

The three sub-zones of this division are recognisable in the Monar area as follows:—

b^5 Semi-pelitic granulites of Maoile Lunndaidh.
b^4 Massive siliceous granulites.
b^3 Moine flags.

Sub-zone b^3—*Moine Flags*—These rocks are platy, splitting up into flags with thin micaceous partings. The bedding is less distinct than in the rocks of b^4, owing to the intensity of shearing, but can usually be traced by the intercalation of thin bands of mica-schist. The rocks of this sub-zone are also, as a whole, much more micaceous, and the biotite occurs in larger individuals than in the overlying granulites. They evidently represent a passage from the original muddy sediments now forming the pelitic gneiss, into the arenaceous arkoses represented by the massive granulites of b^4.

West of the Beinn Dronaig anticline the Moine flags everywhere flank the pelitic gneiss (b^2) and good exposures occur on Beinn Tharsuinn, in Coire Seasgach, and in Coire na Sorna. To the south-west of Beinn Dronaig they form a belt that follows the pelitic gneiss round the southern termination of its outcrop. The two rocks are folded together along the boundary in a series of vertical folds pitching S.S.E., the junction being well exposed on Càrn na Sean-lùibe. The decrease in the breadth of the outcrop

of this sub-zone at this point is doubtless due to the change in the type of folding. In the area south of Maol-bhuidhe the width of the belt again increases, owing to the resumption of the normal type of overfolding, and, since the dip is gentle, the Moine flags extend to a distance of 1 to 2 miles from the boundary of the pelitic gneiss.

Near the west end of Loch Monar these rocks cover a wide area of the lower ground. They are exposed in the burn that connects the Gead Lochs with Loch Monar, and almost surround the Lewisian inlier of Patt Lodge. Rocks of b^3 type are also well exposed in the Amhainn Srath Mhuilich for $\frac{3}{4}$ mile above Strathmore Lodge. The marginal belt that flanks the pelitic gneiss between Bidean an Eòin Deirg and An Gead Loch is also composed of Moine flags, and east of the Strathconon fault-line the same sub-zone forms a belt about half a mile wide that extends eastwards along the northern boundary of the pelitic gneiss of An Riabhachan and the Lewisian inlier of Sgùrr na Lapaich to the foot of the Uisge Misgeach.

Sub-zone b^4*—Massive Siliceous Granulites.*—The rocks of this division follow the outer margin of the belt of b^3 to the south-west of Beinn Dronaig for a distance of 3 miles down the river Ling, and also form all the higher ground along the southern boundary of the Sheet between that river and the Strathconon fault-line. They also cap the summits of An Cruachan and Beinn Bheag.

These massive rocks enter into much of the higher ground to the north of Loch Monar, and are well exposed in the corrie north-west of Bidean an Eòin Deirg. On the east side of the Strathconon line of dislocation the siliceous granulites of b^4 form the low, glaciated hills of Meallan Buidhe, Meallan Odhar, and Beinn Dubh, south of Loch Monar, and also cap the summit of Meall Dubh na Caoidhe on the north side of that loch.

The rocks on Beinn Dubh appear to have a synclinal arrangement. To the north of this syncline schists of a more flaggy character occupy the low ground along the shores of Loch Monar, and probably represent the lowest sub-zone (b^3) of the upper siliceous group.

The behaviour of the numerous pegmatite veins on Beinn Dubh suggests that some degree of resistance to foliation has been locally offered by this massive type of Moine schist. At the western end of the hill the pegmatites are dyke-like in form and run N.W. and S.E. On passing eastwards the rocks become more intensely plicated and the pegmatites are drawn out in a N.E. and S.W. direction parallel with the foliation of the rocks, and show signs of greater shearing. Where the rock was originally very massive and homogeneous it has, though now equally reconstructed, undergone far less mechanical deformation than the semi-pelitic and more laminated rocks, in which the shearing is so intense that it is often difficult to detect any original planes of sedimentation.

The siliceous schists of the Monar area chiefly occupy the lower ground, and where bare of drift form ice-worn hummocks and low hills bearing a scanty heather-moor flora.

The flaggy schists of b^3 give rise to cliffs on Bidean an Eòin Deirg, Beinn Tharsuinn, and in the corries south of Maol-bhuidhe,

but the features due to these rocks are not on so grand a scale as those formed by the pelitic gneiss. C. B. C.

iii. Loch Monar to Gleann Fhiodhaig.

The various members of the Moine Series seen between Loch Monar and the Moruisg—Càrn Liath watershed to the north are similar in type to those found elsewhere in the Sheet.

An infold of the highest member of the Series—the semi-pelitic granulites (b^5)—a remarkably homogeneous and fine-grained mica-schist, is found on the Maoile Lunndaidh plateau. Its occurrence here is of considerable interest, as it is the most easterly exposure of this group in the Sheet, and, as will be seen later, affords invaluable evidence as to the sequence of the various rock-groups in this district.

The massive siliceous granulites of b^4, that occupy the greater part of the area under consideration, comprise light grey quartzo-felspathic granulitic gneisses, with subordinate micaceous bands. The foliation planes in these rocks, and the thin pegmatite veins that traverse them, are often highly contorted. The gneisses break up into large angular blocks, the surfaces of which are extremely resistant to weathering influences. Much of the high ground is occupied by the rocks of this sub-zone, and typical exposures may be seen in the rugged corries that trench the Maoile Lunndaidh plateau. Equally fine sections are also visible round Càrn Gorm, on the north face of Creag Dhubh Mhòr, and in the streams along the north shore of Loch Monar.

Between the massive siliceous granulites (b^4) and the pelitic gneiss, a thin transitional zone of flaggy mica-schist (b^3) always occurs.

In relative proportions of mica, quartz and felspar, this rock is similar to the semi-pelitic schists of b^5, but is easily distinguished by its very flaggy character, the foliation planes being strongly developed. Characteristic exposures flanking the pelitic gneiss may be seen on the plateau between Moruisg and Càrn Gorm, or in the An Crom-allt, a stream flowing northwards from Sgùrr a' Chaorachain into the head of Gleann Fhiodhaig.

The pelitic gneiss (b^2) in this area is a coarse-grained, highly micaceous, and well-foliated rock, invariably garnetiferous. Usually the garnets occur as granular augen, but locally form idiomorphic crystals. Thus, at a small exposure on the south bank of the Meig, rather more than a mile above Corrievuic bridge, the gneiss is studded with well-formed but slightly rounded garnet crystals, about a quarter of an inch in diameter. Another band half a mile east of the summit of Creag Dhubh Mhòr is crowded with smaller but perfect crystals. In both these cases the rock is rich in white mica.

Folding.—The area between the Moruisg—Càrn Gorm watershed and Loch Monar presents a system of deep and nearly vertical folds striking a little east of north. This type of folding is particularly well seen along Gleann Fhiodhaig, and the various bands of schist and gneiss can be followed up the hillsides with the regularity of a sedimentary succession. The folds flatten out on the high ground round Maoile Lunndaidh, and further east assume a highly complex and irregular character.

Order of Succession.—Although over most of the area a definite sequence in the various rock-groups cannot be distinguished, evidence on this important point is forthcoming round Maoile Lunndaidh. A traverse made from the top of this mountain north-eastwards to Meall Doir' a' Bhainne, passes over a complete series of the various types of gneiss and schist with the exception of the lower siliceous zone (b^1). On the summit the semi-pelitic schists (b^5) are seen, followed above Loch a' Chlaidheimh, by the massive siliceous granulites (b^4), the pelitic gneiss (b^2), flanked on both sides by the flaggy mica-schist (b^3), appearing at the west end of the loch. Further to the north-east the siliceous granulites (b^4), again appear, and lastly, at Doir a' Bhainne the Lewisian Gneiss is found.

The section may be interpreted in two ways, according as the fold of pelitic gneiss is regarded as an anticline or a syncline.

If the latter, then the semi-pelitic schists on the crest of Maoile Lunndaidh must be regarded as an infold of the flaggy mica-schist (b^3), the pelitic gneiss having been denuded away. On this hypothesis, the succession would be—pelitic gneiss (b^2), flaggy mica-schist (semi-pelitic granulites) (b^3), massive siliceous granulites (b^4), and lastly the Lewisian Gneiss.

On the second hypothesis, that the fold of pelitic gneiss is an anticline, the semi-pelitic rocks must be regarded as an independent member of the series, and the succession be read as follows :—

5. Semi-pelitic schists . . .	equivalents of sub-zone		b^5
4. Massive siliceous granulites .	„	„	b^4
3. Flaggy mica-schists . . .	„	„	b^3
2. Pelitic gneiss.	„	zone	b^2
1. Lewisian gneiss . . .	„	Group	A.

The first hypothesis, which requires the semi-pelitic granulites to be identical with the flaggy schists of b^3 is difficult to accept on lithological grounds;—the striking homogeneity of the former being a feature never found in the latter zone. The alternative view is far more in accordance with the fact established by the evidence already brought forward, that there is a transgression (whether due to unconformity or thrusting is immaterial) of the Moine Series over the Lewisian rocks.

The succession given above thus seems to be clearly made out; it is, moreover, similar to that already established in other parts of the Sheet. R. G. C.

iv. Strath Bran.

The two streams that flow down the slopes of Creagan nan Laogh and cross the road, the one at Achnasheen, the other ¾ mile to the east, afford excellent sections of the rocks involved in the north-eastern part of the area.

For some distance above the road the eastern stream is flowing over flaggy siliceous schists with thin pelitic bands, similar to the rocks that cover the lower slopes on the opposite side of the Bran valley, and probably belonging to sub-zone b^3 of the Moine Series. These are succeeded, 500 yards up the burn, by a belt of flaky pelitic gneiss (b^2) with two or three small infolds of siliceous schist.

This pelitic band is followed, 1000 yards above the road, by highly siliceous flagstones containing white as well as black mica, that may possibly represent the lower siliceous zone (b^1). Beyond these flagstones the stream flows for 300 yards over an inlier of complex gneisses of Lewisian type, which on its eastern boundary is in contact with the pelitic gneiss (b^2), suggesting an overlap of the base of the Moine Series. Owing to the drift-covered nature of the ground, the different zones cannot be traced far beyond the stream on either side, and the extent of the Lewisian inlier is therefore uncertain. The foliation planes in this section dip steadily to the south-east, at angles of 30° to 50°.

The right-hand branch of the Achnasheen Burn gives a section of rapidly alternating garnetiferous pelitic gneiss and siliceous flagstones, representing the interfolded relation of the two lowest members of the Moine Series. The left-hand, larger stream has cut a deep narrow gorge down the hillside, that coincides very nearly with the N.N.W. strike of the typical pelitic gneiss of Creagan nan Laogh. On the summit of that hill the gneiss is particularly coarse and massive, with abundant idiomorphic garnets and a few lenticular knots of garnet-amphibolite.

The ground along the watershed further to the north-east is largely drift and peat covered, and the boundaries drawn for the pelitic gneiss across Sàil an Tuim Bhàin are therefore conjectural in position.

Further down Strath Bran the Dosmuckeran Burn gives a nearly continuous section of the higher siliceous sub-zones of the Series. The upper part of the stream exposes the siliceous flagstones with biotite-schist bands of b^3; the lower portion flows through gorges cut in the massive felspathic quartz-granulites of b^4. The flags of b^3 are again brought up on another fold along the incipient gorge cut by the River Bran above Dosmuckeran, and to the same zone may be assigned the flaggy siliceous schists with pelitic bands seen along the courses of the Allt a' Bhuird Ruaidh and Allt Chamasaidh, on the south side of the valley. L. W. H.

v. Valley of the Meig and Glen Orrin.

Pelitic Gneiss.—The largest mass of pelitic rocks in the ground to the north of Glen Orrin is involved in the compound anticline of Sgùrr a' Mhuilinn, and surrounds the eastern extremity of the Loch Beannacharain Lewisian inlier, but is truncated on the south-east by the Strathconon fault.

The prevailing lithological type in the areas south of Loch Beannacharain and on either side of the lower part of Gleann Méinich, is a coarse, flaky, muscovite-biotite-gneiss, with wavy folia of felted micas. The muscovite also occurs occasionally in large rounded flakes or "spangles," set at all angles to the planes of schistosity. Thin bands of highly siliceous granulite are often intercalated with the pelitic rock, and probably represent original differences of sedimentation rather than infolds of a higher or lower siliceous series. The gneiss is almost everywhere more or less garnetiferous, and garnets are also found in some of the thin siliceous bands.

In some localities, and particularly on the eastern slopes of Meall na Faochaig, above the River Meig, the gneiss also contains mineral aggregates, rudely prism-shaped, and composed of garnet, quartz and white mica, that stand out in relief on the weathered surfaces. The garnets and garnet-aggregates appear to belong to two generations, as they are often drawn out into phacoids or even into strings along the planes of movement, while in the same rock perfectly idiomorphic garnets can be observed. Both may be attributed to the effects of dynamical metamorphism, but the latter must have been produced when the movements had practically ceased.

The knots and strings of quartzo-felspathic material that characterise the coarser varieties of pelitic gneiss are especially abundant in the flaky rock of Creag Ruadh, along the crest of Sgùrr a' Mhuilinn, and on Meall Buidhe, above Loch Beannacharain.

There is remarkably little variation in the general lithological character of the rock of this zone, and the description given above will also apply to the smaller areas of pelitic gneiss in Glen Orrin.

The relations of the pelitic gneiss (b^2) to the Lewisian inliers, and the nature of the local base of the former in the neighbourhood of Scardroy, are described in Chapter VI., p. 35.

Siliceous Moine Schists.—Banded flaggy quartz-mica-granulites, with occasional thin bands of biotite-schist—representing intercalations of more pelitic sediment—surround the pelitic gneiss of Bac an Eich and form the long ridge of Sgùrr Coire nan Eun, on the north side of the head of Glen Orrin. These rocks have been assigned to sub-zone b^3 of the Moine sequence.

The massive siliceous granulite of the next sub-zone (b^4) appears on the highest part of the Sgùrr Coire nan Eun ridge, but is soon succeeded again to the west by the flagstones of b^3. The rock at the summit cairn contains but little mica, and is characterised by bands in which quartz and pinkish felspar are alternately the predominant mineral. There appears to be an insensible passage from the flaggy micaceous type into the more massive felspathic rock, indicating a gradual diminution in the amount of muddy sediment; and although the typical rock of either zone is quite distinct, it would be difficult to draw a satisfactory boundary line between them on the ground.

The siliceous granulites of b^4 are also well exposed on the steep crags that overlook the Meig valley on the south, a mile to the south-west of Corriefeol. Lines of movement, minute folding and puckering of the colour bands, and other structures suggestive of original lines of current-bedding, are beautifully displayed on the smooth glaciated slabs near the pathway that leads up the glen from Corriefeol.

These granulites also contain a few small knots of garnet-amphibolite, and many veins of pegmatite which cut all the other structure planes.

The steep craggy faces that rise on either side of Glen Orrin above Loch na Caoidhe and Am Fiar-loch are chiefly composed of the massive felspathic quartz-granulites of b^4, the underlying flaggy zone with pelitic bands being exposed in the streams on the lower slopes on the south side of the glen.

At the top of the steep slope that falls to the head of Loch na Caoidhe, and very near the 1750-ft. contour-line, there is a series of remarkable clefts or fissures in the massive granulites, only a few feet in width and descending perpendicularly or with a slight curve downhill for a considerable depth. They appear to have been formed along lines of joint by the action of gravity on the steep hill-face.

These granulites continue in a band of varying breadth along the upper slopes on the south side of Glen Orrin. They are here in contact with the rocks of the Lewisian inlier, and where much interfolded with the latter, as along the eastern tributary of the burn flowing into Loch na Frianich, it is often difficult to separate the Moine granulites from the granulitic acid gneisses of the Lewisian complex. L. W. H.

vi. Glen Strath Farrar.

Basal Conglomerate.—On reference to the map, it will be seen that the Glen Strath Farrar inlier of Lewisian Gneiss is almost entirely surrounded by the siliceous Moine schists. Along the western and south-western margin of the complex, as before stated, a structure resembling conglomerate has been observed in the Moine Series at its contact with the inlier. Where best developed, rounded, oblong or elliptical blocks of siliceous rock are enclosed in a more micaceous matrix. The blocks consist partly of quartzite, and partly of siliceous granulite containing a small amount of mica; their elongated form is evidently a result of shearing movements. If these fragments have been derived from an underlying Lewisian floor, the absence of included fragments of hornblende-schist, and of the other unrepresented members of the complex, may be accounted for on the supposition that these rocks proved less resistant than the siliceous types, and that pebbles of these substances originally present in the conglomerate, have become unrecognisable under the shearing movements. They may perhaps be represented by certain irregular micaceous patches in the groundmass. In one place the matrix of the conglomerate is highly epidotic, suggesting a comparison with the epidotic grits which occur at the base of the Torridonian, where it rests in a similar manner, but of course in an unsheared condition, upon the Lewisian Gneiss.

The conglomerate can be traced for a mile or two along the southern and eastern margin of the inlier to the south of the River Farrar. At a point about half a mile west of Inchvuilt, some little patches of heavy minerals were found in rocks of the Moine Series, situated, like the conglomerate, close to the margin of the older gneiss. These minerals — magnetite, epidote and garnet—are identical with those obtained by washing from the alluvium of a neighbouring stream which flows over the Lewisian rocks. They thus furnish proof of the sedimentary origin of this portion at least of the Moine Series.

Traces of conglomerate have also been found on the eastern (or lower) margin of the gneiss on the flanks of Sgùrr na Muice. The dip is here to the west, and the Lewisian Gneiss, which forms the lower part of the hill-face, overlies the siliceous schist, which occupies the flatter ground at its base.

Along the eastern slopes of the valley of Allt a' Choire Dhomhain, and around the foot of Loch Monar, the schists are pierced by an unusual number of intrusions of pegmatite. The veins have frequently a definite trend to N. 20 W. but at other times their course is quite irregular.

The Lewisian inlier east of Beinn na Muice is followed to the east by a wide belt of siliceous granulite. This again is succeeded by an alternating series of micaceous and siliceous rocks, and still further to the east follows a broad band of pelitic gneiss running north and south through Loch a' Mhuillidh. Much of the pelitic gneiss of this area is characterised by the presence of small well-formed crystals of tourmaline.

The wide belt of siliceous granulite first mentioned becomes rapidly interfolded with rocks of the pelitic zone to the south of the Orrin-Farrar watershed, until along the mountain ridge that separates the two valleys the ground is almost entirely occupied by successive bands of pelitic rock separated by thinner outcrops of siliceous material.

The swing of the successive zones of metamorphic rock around the major fold that occupies the south-eastern corner of the area is very noticeable on the map.

From the Glen Cannich watershed the schists strike north-eastwards over Creag Dhubh into Glen Strath Farrar. A little to the south of the Orrin-Farrar watershed the strike changes from north to north-west, and then, bending abruptly round to the east, passes into Glen Orrin in a direction slightly to the north of east.

A noticeable striation or striping has been observed in the faces of the laminæ in the rocks of this district. It is probably due to small parallel corrugations of the ultimate micaceous layers. The pitch of the small folds corresponds in most cases exactly with the direction of striation in the surrounding rocks, and the latter has also a certain persistence in relation to the strike.

Thus, where the beds are vertical, the striation dips south-east, south or south-west, according to the direction of the strike; when the beds are inclined, the direction of striping is indicated by the above rule, on the supposition that the beds have been tilted over from a vertical position.

This applies not only to the rocks of the Moine Series but also to the Lewisian Gneiss, which also in places shows marked striation.

E. M. A.

vii. Glen Cannich.

Between the summits of Sgùrr na Lapaich and Bràigh a' Choire Bhig, and forming the crags that surround the wild corrie of Loch Tuill Bhearnach, there is interfolded with the pelitic gneiss a belt of rock somewhat different in character from the other members of the Moine Series in this area.

It is a flaky, felspathic, quartz-mica-granulite, with a white or pale-greenish mica as the predominant mineral; pinkish felspar and abundant small garnets of a very pale colour. A closely similar rock occurs on the north side of Sgùrr na Lapaich and also on Beinn Dronaig. At the latter locality the evidence brought forward by Dr. Crampton shows that this quartz-mica-granulite lies between

the pelitic gneiss (b^2) and the Lewisian complex (Ⱥ), and represents the lowest zone (b^1) of the Moine Series.

The pelitic rocks that form the ridge and southern slopes of An Riabhachan are almost entirely of the coarse, massive, flaky type, with large garnet aggregates. On Sgùrr na Lapaich and Bràigh a' Choire Bhig, a finer grained, semi-pelitic rock is associated with the coarser gneiss, and is characterised by bands containing numerous small idiomorphic garnets.

Further to the east along the northern slopes of Glen Cannich, a complex system of rapid isoclinal folding gives rise to an alternation of bands of pelitic gneiss (b^2) and the flaggy siliceous and semi-pelitic schists of b^3. In the neighbourhood of Loch Carrie the strike is northerly, but towards the west it swings in a west-south-westerly direction round the end of the large fold that passes out of the map to the west of Coire an t-Sith. L. W. H.

viii. Description of Horizontal Sections across the Area.

Fig. 6, *p.* 70.—The western portion of this section depicts the effect of the Glen Docherty fault by which the outcrop of the Moine thrust has been shifted westwards for about a mile from Glen Cruchallie to the Kinlochewe Hotel.

Above the Moine thrust-plane there is a thin development of dark wavy mica-schist (b^2, Fig. 6), which is believed to represent the zone of muscovite-biotite-schist that appears six miles to the east on Creagan nan Laogh. The broad intervening area is occupied by rocks of variable character, though referred for the most part to the quartz-granulite group (b^3, b^4, Fig. 6) of the Moine Series. For example, flaggy siliceous granulites (b^3), containing a band of augen-schist, are developed in the west part, and these are followed by alternations of quartzose and thin pelitic schists as far as Allt Duchairidh, while beyond that stream almost to the margin of the muscovite-biotite-schist of Creagan nan Laogh there is a series of massive schists (b^4) impregnated with pegmatitic material.

The prominent structural feature north of Achnasheen is the broad belt of pelitic gneiss, extending eastwards to Druim Dubh, in the core of which there is an upfold of Lewisian Gneiss (Ⱥ, Fig. 6). It is noteworthy that on the eastern limb of this arch thin bands of siliceous schist, believed to represent the lower siliceous zone (b^1, Fig. 6), are in contact with the Lewisian Gneiss. These bands have not been found on the western limb.

This characteristic zone of muscovite-biotite-gneiss is followed by alternations of mica-schist and siliceous schist (b^3, Fig. 6), which are succeeded by the granulitic schists of b^4, occupying the centre of a compound synclinal fold in the Bran valley.

On the eastern limb of this flexure there is a band, about a hundred yards across, of flaggy muscovite-biotite-schist, which is correlated with the zone of similar material on Creagan nan Laogh and Druim Dubh (b^2, Fig. 6). It is followed in inverse order by flaggy quartz-schists, believed to represent the lower siliceous zone of the Moine Series (b^1, Fig. 6), as they are in immediate contact with basic and ultrabasic rocks of the Lewisian complex on the northern face of Sgùrr a' Ghlas Leathaid. Indeed the feature of special

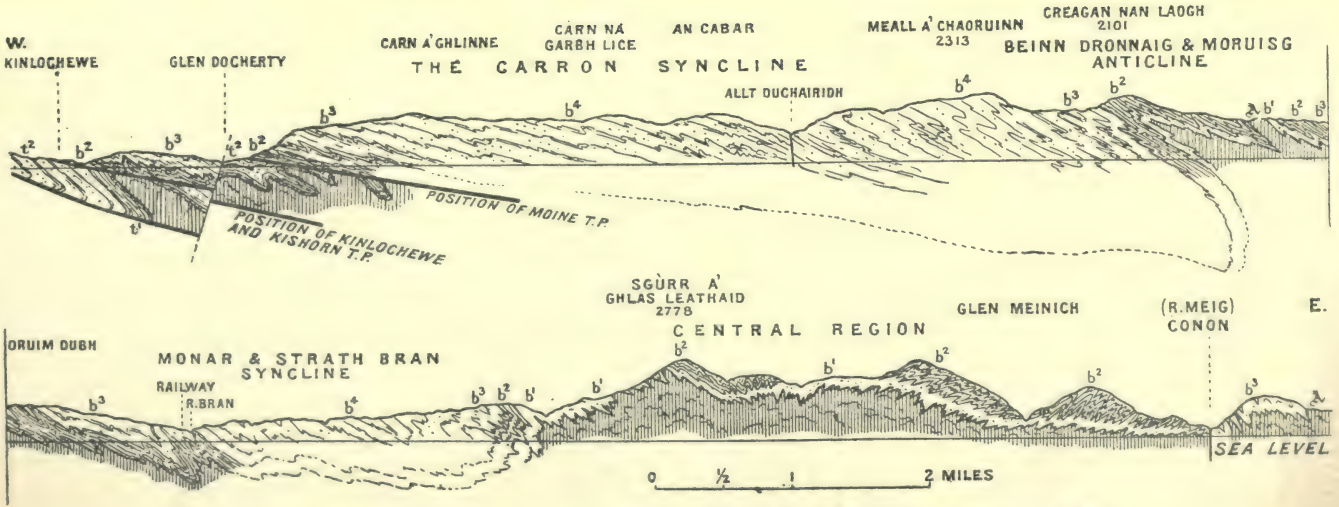

FIG. 6.—Diagrammatic Section across the Northern Region from Kinlochewe to the River Meig.

Moine Series { b^4. Massive siliceous granulites. b^3. Flaggy siliceous schists. b^2. Pelitic gneiss. b^1. Lower siliceous schists.

t^2. Applecross Group } Torridonian.
t^1. Diabaig Group }
A. Lewisian Gneiss

interest on the northern declivity of that mountain is the reduplication of Lewisian rocks with infolds of the lower siliceous zone and the overlying pelitic gneiss. At length, near the crest of Sgùrr a' Ghlas Leathaid, the Lewisian Gneiss disappears beneath the lower siliceous schists, which are capped in turn by the succeeding zone (b^2).

In the hollow between the two peaks of Sgùrr a' Mhuillin the lower siliceous zone appears and is followed in a S.S.E. direction by the pelitic gneiss, which extends continuously to Strath Conon, where the latter is brought into conjunction with Lewisian Gneiss and siliceous schist by the great fault traversing that valley.

It is observable that, along this line of section from the Moine thrust-plane to the crest of Sgùrr a' Ghlas Leathaid, all the structures, including the planes of foliation and planes of bedding, are inclined to the E.S.E. or south-east at comparatively low angles. But on the plateau of Sgùrr a' Ghlas Leathaid and Sgùrr a' Mhuillin there seems to be a fan-shaped arrangement of the folding, the axial planes being vertical or nearly so in the area between these peaks with inward dips on either side. E. G., B. N. P., L. W. H.

Fig. 7, *p.* 72.—The displaced Lewisian Gneiss above the Kishorn thrust appears on the west side of Strath Carron on Càrn Eididh, but the relations of the Moine Series to this mass are not visible in the line of section. The position of the Moine thrust is obscured by the alluvial deposits of the Carron. It is probable, however, that it is thrown down by a normal fault as represented in the section.

The rocks on the east side of the valley consist of flaggy quartzose Moine schists and puckered pelitic schists (b^3, b^2, in Fig. 7), with a small core of granulitic felspathic gneiss with actinolite, which has been correlated with the Lewisian Gneiss (Ⱥ, in Fig 7).

From the crest of the ridge eastwards to the slopes of Sgùrr Choinnich the geological structure is a counterpart of that already described in the section between Attadale and Beinn Dronaig. The same zones appear in the same relative order, occupying the Carron syncline. On the western limb the massive Moine schists at the head of the Allt Coire Taodail (b^4) are followed by flaggy muscovite-schists streaked with magnetite ($b^{4'}$), which are succeeded by fine grained biotite-granulites (b^5) forming the crest of the ridge of Creag a' Chaoruinn Eagan. In the eastern limb, these zones are repeated in inverse order till, on the higher slopes of Sgùrr Choinnich, we find pelitic gneiss (b^2, Fig. 7). B. N. P.

The line of section now follows the crest of the ridge between Sgùrr Choinnich and the Bidean an Eòin Deirg, exposing the pelitic gneiss (b^2) lying on the Lewisian Gneiss (Ⱥ). The latter reaches the surface at one point on Sgùrr a' Chaorachain in the heart of the Beinn Dronaig anticline. To the east of the summit of Sgùrr a' Chaorachain the pelitic gneiss is gradually replaced by the Moine flags (b^3) which form the Bidean, and these in turn by the overlying massive siliceous schists (b^4) of the eastern flank of that mountain. To the west of the summit of the Bidean, the Lewisian Gneiss (Ⱥ) comes to the surface in a narrow belt which is seen in cross-section. It is here in contact with the rocks of b^3, whereas on Sgùrr a' Choinnich it is surrounded by the pelitic gneiss (b^2). C. B. C.

The massive siliceous granulites (b^4) form the slopes on each side of Srath Mhuilich. Further east, on the tableland of Maoile

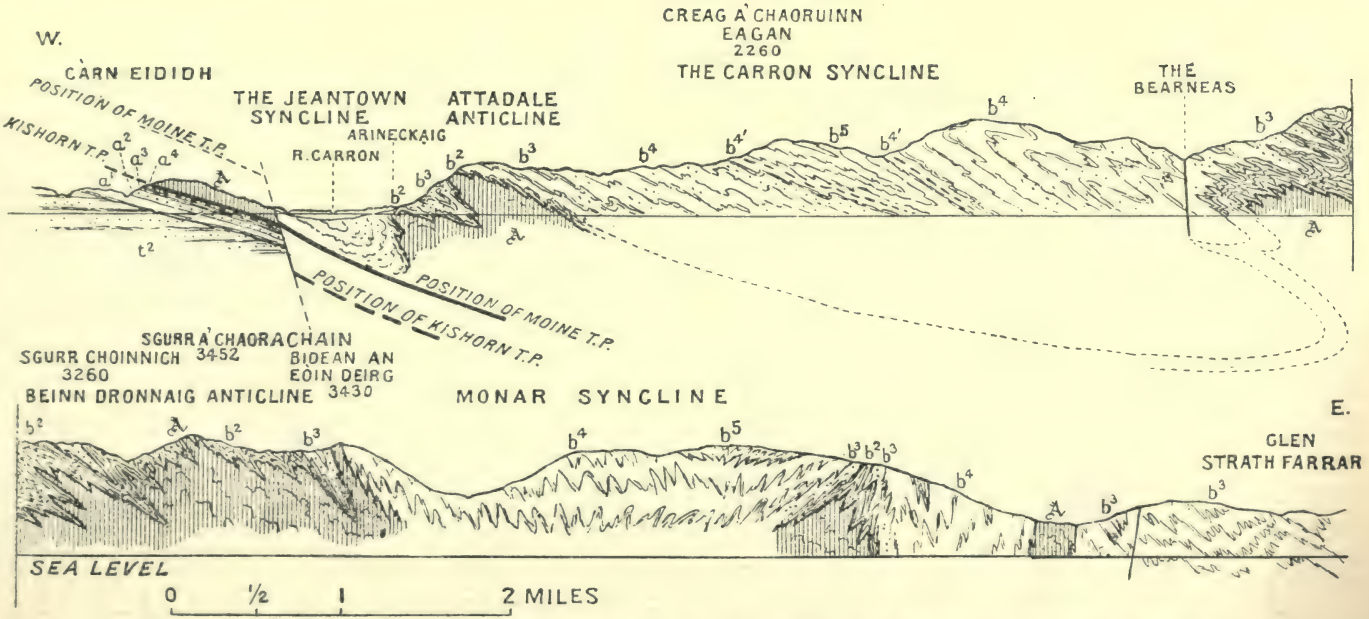

FIG. 7.—Diagrammatic Section across the Central Region, from Arineckaig in Strath Carron to Glen Strath Farrar.

- a^4. Serpulite Grit
- a^3. Fucoid Beds
- a^2. "Pipe Rock"
- a^1. Basal Quartzite

} Cambrian.

- t^2. Torridonian (Applecross Group).
- b^5. Semi-pelitic schists
- $b^{4'}$. Magnetite granulites
- b^4. Massive siliceous granulites
- b^3. Flaggy siliceous schists
- b^2. Pelitic gneiss

} Moine Series.

- Ā. Lewisian Gneiss.

Lunndaidh, there is an infold of fine grained biotite-granulites, correlated with the similar zone found in the heart of the Carron syncline, and marking the highest zone of the Moine Series. On the eastern slopes of Maoile Lunndaidh, the siliceous granulites again appear, and are repeated on each side of an anticline, in the centre of which the Moine flags (b^3) are seen. Still further east, in the main valley on the north shore of Loch Monar, a further anticlinal fold brings up the complex of Lewisian gneisses.

As illustrating the discordant relations of the Moine Series with the Lewisian rocks, it should be noted that although the siliceous granulites (b^4) occur on both sides of the complex, the Lewisian rocks themselves are not arranged in a symmetrical fold, the successive bands met with in the complex, reading from west to east, being—garnet-amphibolite, crystalline limestone, calc-silicate-schists and graphite-schist. R. G. C.

Fig. 8, *p.* 74.—At the western limit of this section flaggy siliceous schists appear above the Moine thrust-plane, followed by mica-schists and phyllites at Lochcarron. East of the sea-loch the Lewisian Gneiss (A) comes to the surface along a series of compound anticlinal flexures about a mile in width with successive infolds of muscovite-biotite-gneiss (Fig. 8, b^2), overlaid by granulitic quartz-schists representing the lowest sub-zone of the upper siliceous group (Fig. 8, b^3).

Between the Attadale valley and the western slopes of Beinn Dronaig, various subdivisions of the Moine Series are arranged in a great compound syncline (the Carron syncline), and appear in what is believed to be the normal sequence on its western limb. Beyond Attadale the flaggy siliceous schists with alternations of mica-schists (Fig. 8, b^3) are succeeded by a broad belt of very massive Moine schists with bands of augen-schist (Fig. 8, b^4). Eastwards, there is a zone of flaggy quartzose schists much streaked with magnetite, followed by fine-grained semi-pelitic biotite-granulites (b^5), forming here the highest member of the Carron syncline. Beyond Càrn Geuradainn these various subdivisions of the Moine Series are found in inverse order, till the basal members reappear in contact with the Lewisian Gneiss of Beinn Dronaig.

Over this part of the line of section east of Lochcarron the dip of all the structures is towards the south-east at comparatively low angles, thus indicating isoclinal folding of the zones both on a large and small scale. B. N. P.

The section through Beinn Dronaig is taken to the north of the peculiar belt of folding described elsewhere (Chapter VIII.). The lowest member of the Moine Series, the lower siliceous schists (b^1), appears from beneath the pelitic gneiss (b^2) on Beinn Dronaig. This member, which is missing on the western limb of the Carron syncline, here surrounds a small exposure of the Lewisian Gneiss, which appears at the surface in the denuded core of the Beinn Dronaig anticline. To the east of the summit the lower siliceous zone (b^1) and the pelitic gneiss (b^2) again occupy the ground as the eastern limb of the Beinn Dronaig anticline, or western limb of the Monar syncline. Near An Cruachan they are succeeded by the upper siliceous group, which continues to form the ground up to the Strathconon fault. On An Cruachan the Lewisian Gneiss again comes to the surface and forms part of the summit of the hill, which

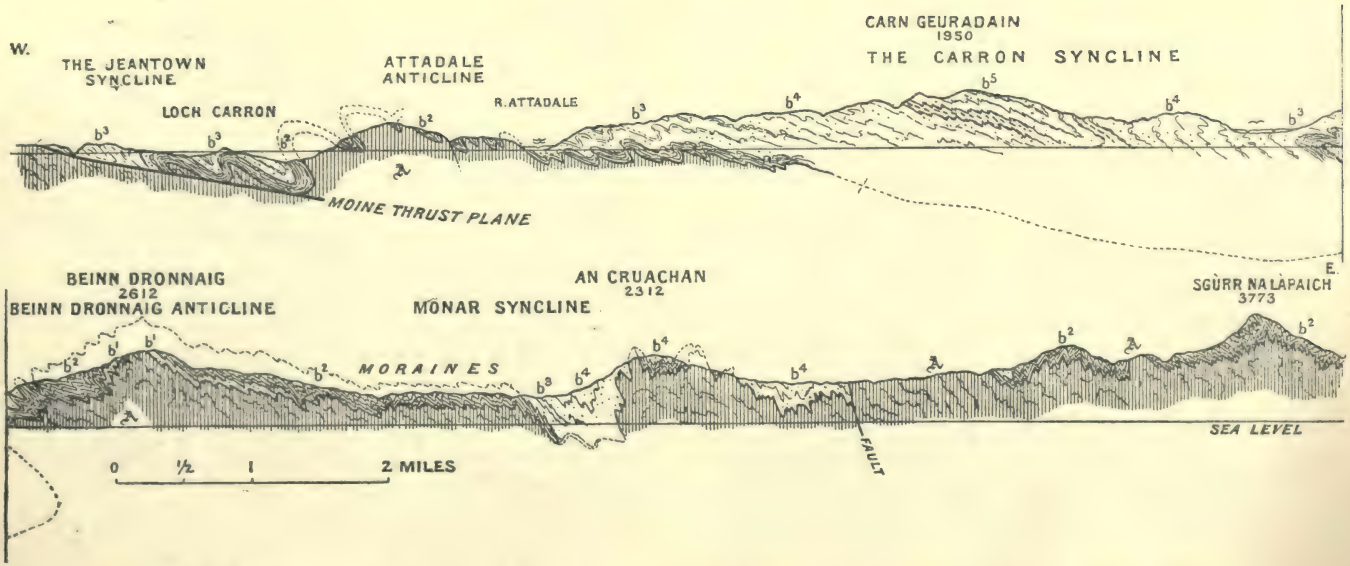

FIG. 8.—Diagrammatic Section across the South-Western Region, from Loch Carron to Sgùrr na Lapaich.

Moine Series
- b^5. Semi-pelitic schists.
- b^4. Massive siliceous granulites.
- b^3. Flaggy siliceous schists.
- b^2. Pelitic gneiss.
- b^1. Lower siliceous schists.

Lewisian Gneiss.
Raised Beach.
Alluvium.

retains, however, an isolated cap of the upper siliceous zone (b^4). It is obvious that the underlying Lewisian Gneiss is here in contact with higher members of the Moine schists than in areas further to the west. To the east of the fault the Lewisian Gneiss appears at the surface for more than a mile, followed further to the east by the pelitic gneiss, which forms the greater part of Sgùrr na Lapaich, and overlies the Lewisian Gneiss in a complicated system of folds which are chiefly isoclinal and dip to the east. C. B. C.

CHAPTER IX.

IGNEOUS ROCKS.

i. Pre-Foliation Igneous Rocks.

EASTERN AREA.

The pre-foliation intrusions of amphibolite and hornblende-schist that are so abundant along certain belts in the Moine schist areas in the adjoining Sheet to the east (83), are conspicuous by their absence over the greater part of the area under consideration. Small knots and lenticular masses of imperfectly foliated garnetiferous hornblende-rock occur in the coarse pelitic gneiss of Meall Buidhe, south of Loch Beannacharain, and also along the crest of Meall na Faochaig, where they are also found in the flaggy quartz-granulites of b^1.

These are presumably of igneous origin, and may represent the fragments of an intrusion whose original continuity has been destroyed by later movements.

A single band of thoroughly schistose, fine-grained amphibolite has been traced for several hundred yards through the quartz-mica-granulites on the east side of An Sìthean, to the north of the head of Glen Orrin.

Certain dyke-like bands of hornblende-biotite-gneiss to the north of the head of Loch Beannacharain have already been referred to in the description of the Lewisian inliers. They are distinct in character from the epidiorites of the Moine Series (see p. 34).

L. W. H.

The garnet-amphibolites mapped on both sides of the Meig valley are all of much the same character. They are usually unfoliated in the centre, while along the edges and also along certain lines within the mass, the rock is in the condition of fine hornblende-schist. It is not easy to demonstrate the intrusive nature of these rocks, for sections showing the junction with the surrounding schists are extremely rare. The best is undoubtedly that on the west side of the amphibolite mass 1¼ miles east of Càrn Gorm, where the line of contact is laid bare for several yards. At more than one point there are slight indications of a transgression of the amphibolite across the foliation planes of the schist, but the latter seems to be in no way altered. A band of heavy minerals occurs in the amphibolite just within the junction line.

R. G. C.

Bands and lenticular masses of hornblende-schist or epidiorite occur in the Moine Series in various parts of Glen Strath Farrar, and are particularly abundant in the zone of alternating pelitic and

siliceous schists which crosses the Farrar about a mile above Ardchuilk. E. M. A.

MONAR AREA.

A few thin bands of dark-green hornblende- and chlorite-biotite-schist occur in the East Monar Forest and in the ground immediately east of Beinn Bheag. They have a northeast-southwest trend, parallel to the strike of the flaggy siliceous schists with which they are associated, and are confined to a narrow belt which preserves the same line of strike although apparently shifted for about 3 miles by the Strathconon wrench-fault.

Garnetiferous amphibolites of a more massive character than the above, are found in association with the pelitic gneiss of the Beinn Dronaig anticline. They are seldom more than 50 ft. in breadth. Bands and lenticles of these rocks are seen on Beinn Dronaig, at several points along the waterparting south of Strathmore, on Sgùrr na Conbhaire and on the southern flanks of Sgùrr a' Chaorachain.

Similar rocks are found in several places near and within the northern margin of the pelitic gneiss of An Riabhachan.

Outside the pelitic gneiss area one only of these garnet-amphibolites was met with, on the south-east flank of Beinn Bheag, where it is in association with rocks of siliceous Moine type, containing bands of hornblende-chlorite-schist. C. B. C.

ii. Post-Foliation Igneous Rocks.

EASTERN DISTRICT.

A single post-foliation dyke with an east and west trend traverses the Lewisian Gneiss on the northern slope of the valley, 1 mile west of Scardroy. The rock is a normal vogesite, with a brick-red weathering and chilled margins. Two other small dykes, belonging to the lamprophyre group, occur in the Moine schists of Coire an t-Sith, on the north side of Glen Cannich. The larger of these is only 4 feet in width, and is vesicular in the central portion.

L. W. H.

Pegmatite veins, which are probably of intrusive origin and later than the foliation, occur in various parts of the Glen Strath Farrar area. They are especially numerous on the eastern slopes of the valley of the Allt a' Choire Dhomhain. Dr. Flett describes a specimen from one of these veins as a coarse grained mixture of orthoclase and quartz with a little plagioclase.

Lamprophyre dykes are widely distributed, though nowhere very abundant. They have a common direction—10° or 20° north of east—and can be divided into two easily distinguishable classes. One of these is dark grey in colour, and belongs to the camptonites. The other class has a reddish tinge, and is allied to the vogesites.

E. M. A.

MONAR AREA.

Narrow dyke-like intrusions of later age and of different lithological character are fairly numerous in the districts of An Riabhachan and the Uisge Misgeach. Their trend is usually parallel to the general

E.N.E. strike of the schists, but varies with it from place to place. In some cases, however, they seem to have been intruded along joint-planes or fault fissures. They are most frequently met with along a belt extending from the valley of the Uisge Misgeach in a W.S.W. direction along the lower slopes of An Riabhachan to the Coire nan Each.

The intrusions vary in breadth from a few inches up to 12 ft., are dark grey in colour, and usually very fine grained. They traverse indifferently the pelitic and siliceous rocks of the Moine Series and the Lewisian Gneiss. In the bed of the Allt Garbh-choire, near its junction with the Uisge Misgeach, one of these dykes is found cutting another. Dr. Flett has described one of the specimens from this locality as an augite-minette (12427)—the other (12426), as a fine-grained olivine-basalt. In the section the basalt is cutting the minette.

At the head of the Garbh-choire, on the east side of Sgùrr na Lapaich, a lamprophyre can be followed almost perpendicularly down the cliff nearly to the bottom, where it turns round and runs up the cliff about 50 yds. further to the south, in a direction almost parallel to its former course. The intrusion is evidently following the planes of schistosity along the parallel limbs of an isoclinal fold. At the point where it passes round the crest of the fold it has been subjected to a later movement, by which it has been sheared into a hornblende-schist. This sheared rock is described by Dr. Flett as "a biotite-hornblende-schist, resembling a sheared lamprophyre (vogesite)" (12430). Specimens taken from the parallel unsheared limbs he refers to as "biotite-vogesite of peculiar type" (12431). The latter is accompanied by a camptonite (with porphyritic felspar) (12432), and a monchiquite (12433), which are probably members of a later series of intrusions that have entered the same fissure in which the vogesite had previously been injected. C. B. C.

PETROGRAPHY.

The igneous rocks that occur in the Moine gneisses of this Sheet may be divided into two sets, namely, those that are older than the development of foliation in the gneisses, and those that are of later date than the foliation.

I. The pre-foliation igneous rocks are all of basic composition. They are completely metamorphic, having presumably been re-crystallised by the movements that induced the foliation in the Moine schists, and are now hornblende-schists and amphibolites often rich in garnets. Sometimes they contain biotite; and sphene, iron oxides and apatite rather constantly appear as accessory components. Quartz and felspar are practically always present. Pyroxene, on the other hand, is invariably absent, and the igneous structures are completely obliterated by the metamorphism. These Moine amphibolites are singularly constant in their characters over a wide area of the north and west of Scotland; those that occur in the Ross of Mull are almost identical in composition and structure with those of eastern Sutherland.

II. The post-foliation igneous rocks fall naturally into three groups.

a. The Foliated Lamprophyres and Lamproschists.—This is a very peculiar series of dykes, of which examples are known all over the

Scottish Highlands from Central Perthshire to Caithness, and from the Ross of Mull to the east coast of Inverness-shire. Possibly the foliated lamprophyres of Colonsay and Islay also belong to this group. They often form well defined dykes and sills, but are rather inconstant in direction. Sometimes they are perfectly foliated greenish schists, rich in chlorite and pale-green hornblende; at other times they are nearly normal igneous rocks, principally vogesites and minettes. Every intermediate stage between these extreme conditions may be found, and often the same dyke varies considerably in the degree of its metamorphism from place to place. They are apparently not numerous in this Sheet, the only one sliced for microscopic examination being that which occurs in Coire nan Each of the Garbh-choire, Sgùrr na Lapaich (12430–1). A full account of the chemical and petrographical peculiarities of these rocks will be found in the Memoir on Sheet 93, the Ben Wyvis and Carn Chuinneag area, where they are very common and exhibit a great diversity of types. Neither their age nor the period at which they acquired their foliation can be definitely fixed at present.

b. The Normal Vogesites and Minettes.—These are by no means scarce in this Sheet, though the individual dykes cannot be followed for any great distance. They exhibit no sign of metamorphism, but in all respects resemble the lamprophyres of the Newer Granite Series that have such an extensive development in the Highlands south of the Great Glen. Many of the minettes contain green augite in addition to lustrous plates of brown biotite, and occasionally they show a nodular or spheroidal character with rounded bodies, as large as peas, that weather out prominently on exposed surfaces (11638 Garbh-uisge, 400 yds. above its junction with Uisge Misgeach). In the Southern Highlands the dykes of this kind have a fairly constant north-east trend, but in the area at present under consideration they vary a good deal in direction, some being north-east, others north-west and still others east-and-west.

c. The Olivine Basalts, Monchiquites and Camptonites.—Scattered over the Northern Highlands of Scotland there are many sporadic occurrences of dykes belonging to this class. They occur, for example, in Caithness, in Eastern Sutherland, and in the Glenelg district; but their principal centre is the Orkney Islands, where they are found in great numbers. These dykes are always unfoliated and often remarkably fresh. In Coire nan Each a minette dyke is cut by one of the camptonites, which proves that these are the latest intrusions of this area. On Dunnet Head in Caithness they traverse the Upper Old Red Sandstone. Most of the authorities have considered it probable that this series is of Tertiary age and has proceeded from the great eruptive foci that were active along the west side of Scotland in Eocene or Miocene time; but this has not been universally accepted and under the circumstances it is difficult to prove.

A very interesting feature of this group of intrusions is the constant association of olivine-basalts with the lamprophyric camptonites. This association has also been noted in the Orkneys, in Colonsay, and the Ross of Mull, and it cannot be accidental, since very clear transitions between the different types occur in considerable numbers. In this Sheet, for example, there are olivine-basalts

in Coire an t-Sith, Glencannich (13016), Allt Garbh-choire of Sgùrr na Lapaich (12426), and Allt Uchd Rodha (4000 ft. above the bridge, 11634). They are rather fine-grained and non-ophitic; some of them contain much olivine in micro-porphyritic crystals, but there is nothing exceptional about them except that they have a little more red-brown biotite than is usual in basalts or dolerites. Their augite has a purplish-brown colour but analcite is scarce.

Other rocks are virtually olivine-dolerites in which small rounded spots occur (ocelli) with abundant deep-brown hornblende, and felspar in crystals that are sometimes branched and brush-like. This is a very important characteristic of the camptonites. An example of this class occurs in Garbh-uisge, 600 ft. above its junction with the Uisge Misgeach (11657).

Typical camptonites also occur, with abundant dark-brown hornblende, porphyritic purple augite and olivine (12419 Allt Riabhachain, 11635 1700 ft. S.S.E. from Inchvuilt). An abnormal variety of camptonite occurs in Coire nan Each, Sgùrr na Lapaich (12432), which, in addition to phenocrysts of augite and olivine, contains porphyritic plagioclase felspar.

Lastly, we may mention a monchiquite from the same locality (12433) which has a very small amount of plagioclase and very little analcite. It might equally well be called a limburgite, except for its close association with the camptonite dykes of this district.

The dykes of this group seem on the whole to have an east-north-east trend, the same as that of the Caithness and Orkney dykes, but in some places they run east-and-west, and they have apparently availed themselves of the pre-existent fissures in which the minettes and vogesites had been injected, since, in Garbh-choire, a dyke of camptonite is found side by side with a minette.

J. S. F.

CHAPTER X.

Faults.

The Strathconon fault, which crosses the south-eastern corner of the map, and has already been described as one of the most important structural features of the area, belongs to the system of great northeast-southwest wrench-faults that traverse the northern Highlands.

The evidence obtained at various points on either side of Loch Monar and also in the Glenelg district (Sh. 71), where the fault passes out to sea, indicates that the movement along the fault has been on a large scale and the wrench from right to left—the observer looking north—causing the strata on the west side of the fault to move in a southerly direction, those on the east side to the north.*

In the area north of Loch Monar the lateral movement is shown by the torsion of the strata towards the fault, and by the horizontal striæ observed on slickensided surfaces along the lines of crush. The amount of crushed and disintegrated material in the neighbourhood of the fault indicates the intensity of the movement. In Gleann Chorainn and Glen Orrin the zone of crushed and hæmatite-stained rock is in places more than a mile in breadth, and numerous subsidiary lines of crush, slightly oblique to the main wrench-line, traverse the schists near Loch na Caoidhe. The deformation of the rocks is especially noticeable along the lower part of Gleann Chorainn, and along a subsidiary crush which follows the course of a small burn that falls into Loch na Caoidhe on the north side. In the latter locality the horizontally slickensided surfaces are well seen. The more basic and pelitic rocks are often converted into a soft black unctuous schist, with white mica along the gliding planes, while the more siliceous members are crushed and stained, or completely broken up into a coarse epidotic breccia.

In the Meig valley and in Gleann Chorainn the pelitic gneiss (b^2) is faulted against the siliceous members of the Moine Series, the discordance in strike on either side of the fault being very marked. Further west, in Glen Orrin, two small Lewisian inliers are truncated and do not reappear on the eastern side anywhere to the north of Loch Monar. L. W. H.

From the head of Glen Orrin the belt of crush and dislocation crosses the Monar basin in an almost straight line with a south-westerly trend, and passes out of the map to the west of the mountain mass of An Riabhachan.

On the north side of the basin the fault defines the course of the Allt na Cois for a distance of half a mile, and appears again

* "The Geology of Glenelg, Lochalsh and South-East Part of Skye," *Mem. Geol. Survey*, 1910, p. 148.

on the northern shores of Loch Monar at Lùb-an-inbhir, where the crush zone has induced the sharp turn in the Allt a' Choire Fhionnaraich near its mouth.

On the southern side of the loch the fault-line appears about half a mile east of Aultfearn, and west of Meallan Buidhe crosses the southern tributaries of the Allt Riabhachain, giving rise, in two of these streams, to small waterfalls. Further to the south-west it can be followed along the eastern slope of the hollow drained by the Allt Coire nan Each till it passes out of the Sheet.

To the south-west of Meallan Buidhe the Lewisian rocks and the pelitic Moine gneiss are consecutively thrown for a distance

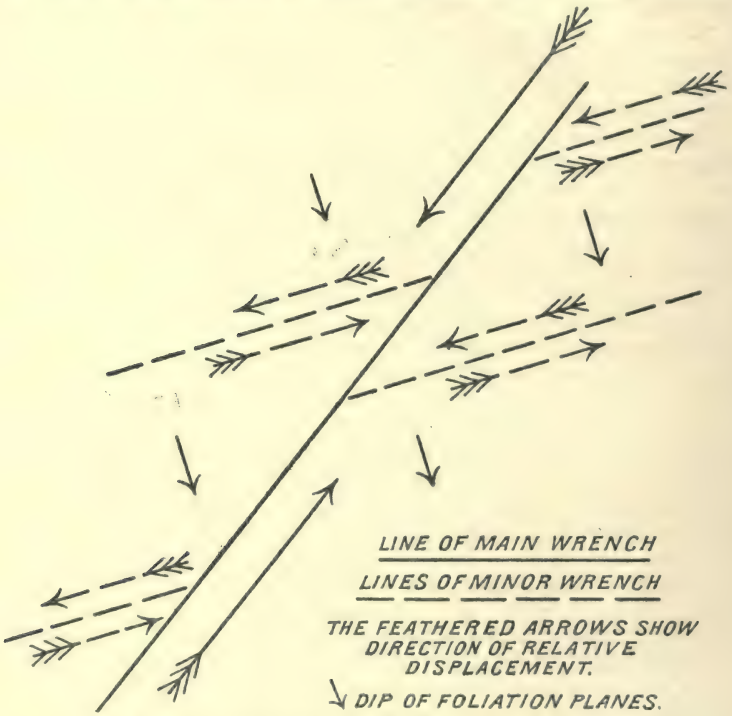

Fig. 9.—Diagram showing the Relation of the minor faults to the main Strathconon Wrench fault.

of 2 miles against the higher siliceous Moine schists on the north-west side of the fault.

The relative positions on either side of the line of dislocation of the zone of pegmatite veins in the siliceous schists of Beinn Dubh, and also of the belt of hornblende-schist intrusions in the East Monar Forest referred to on p. 77, indicate a displacement of the rocks along the north-west of the wrench for about 3 miles in a south-westerly direction.

In the latter case, however, an accurate estimate of the amount of displacement is difficult, owing to the acute angle made by the strike of the rocks with the line of fault.

The facts detailed above tend to confirm the evidence obtained elsewhere along the line, that the direction of lateral movement was to the north-east on the eastern side of the wrench and to the south-west on the western side.

The main line of dislocation is flanked on either side by smaller faults, which converge towards it in such a manner that their more or less parallel course lies more directly east and west than that of the main fault, and almost in the same direction as the strike of the Moine schists. To the north of Loch Monar these minor faults are most abundant on the east side of the wrench, and converge towards it in a southerly direction.

The convergent angle made by these flanking faults with the main line of rupture may possibly be explained on the assumption that the foliation planes of the schists are lines of weakness—an assumption supported by the fact that the later lamprophyre intrusions in this area follow the strike of the schists.

During the movements the rocks on either side of the wrench would tend to find relief by means of block adjustment along these planes of weakness.

The lamprophyre dykes referred to above are confined to a narrow belt of country in the southern part of the Monar area, and are continued across the line of the Strathconon wrench without any displacement, having evidently been intruded at a later date than that of the faulting. C. B. C.

The Loch Maree or Glen Docherty fault belongs to another system of north-west and south-east lines of crush and dislocation. It enters the map at Kinlochewe, crosses the Bran valley at the head of Loch a' Chroisg, and runs with a general E.S.E. trend through the hollow of Loch Beannacharain. At the foot of that loch it appears to be cut off by the Strathconon fault, which is therefore presumably the later of the two.

The amount of deformation along the line of this fault is very marked in Glen Docherty, where the flaggy siliceous granulites are broken up into a subangular breccia which is seen along the bed of the stream at various points. Similar crushing and brecciation appears in the burn at Ledgowan, at the head of Loch Gowan and along the Scardroy Burn. The farther course of the fault to the east is concealed beneath the waters of Loch Beannacharain.

Another line of crush, parallel to the trend of the Glen Docherty fault, gives rise to the deep and picturesque gorge on the south-west side of Meall Buidhe, south of Loch Beannacharain, and several minor examples with the same trend are found along the burns that flow down the west side of Gleann Chorainn.

L. W. H.

CHAPTER XI.

PLEISTOCENE AND RECENT.

i. Glaciation and Glacial Deposits.

General Considerations on the Glaciation of the Area.—Throughout the region under discussion there is abundant evidence of the former presence and movement of ice under different conditions and in different directions over all parts of the area.

The data from which the glacial history of the country may be deduced can be conveniently divided into the phenomena due (1) to erosion and (2) to accumulation.

Under the former head are included—ice-worn and striated surfaces; erosion of cirques; rock-basins; over-deepened and hanging valleys; overflow channels; river gorges initiated before the complete disappearance of the ice from the valleys.

Under the latter—boulder-clay with its included fragments; moraines; erratic blocks; fluvio-glacial gravels (terminal fans and terraces); moraine-dammed lochs.

A further account of these phenomena, as developed in different parts of the area, will be found in the detailed descriptions of each district.

In this region, as in the adjoining country to the north and east (Sheets 93, 83), three phases of glaciation can be recognised.

1. The period of maximum glaciation, during which probably no part of the area rose above the ice-cap, and the ice-shed may have been situated considerably to the east of the elevated region in the S.W., which forms the highest ground in the map. Direct evidence on this point is, however, wanting, as the traces of this, the climax of the glacial period, have mostly been obliterated on the mountain tops by subsequent frost weathering, and on the lower ground by the widespread effects of the later glaciation.

It is now almost impossible to distinguish between the traces of the ice-movement during the period of its maximum development, and those left by the later glaciation that, in its earlier stages, was also on a large scale.

Only those striæ, therefore, which prove that the ice passed over the highest peaks in a westerly direction can be with any confidence referred to the former period. Such striæ, indicating a general westward movement of the great ice-sheet, have been obtained on several of the highest mountains in the west. They occur, pointing W.25N. on the summit of An Ruadh-stac, at a height of 2919 ft.; W.N.W. on the highest peak of Glas Bheinn at 2330 ft.; and on

Sgùrr na Feartaig, 3½ miles south-east of Achnashellach, pointing north-west, at over 2750 ft.

The same difficulty is found with the glacial deposits. In many of the valleys, as in that of the Carron and its tributaries, of the Attadale stream and of the Ling, a light, fawn-coloured stony boulder-clay is often found underlying deposits obviously morainic or fluvio-glacial in origin.

This may in some cases represent the material laid down during the period of maximum glaciation, but no criterion has been found by which to distinguish this from the *moraine profonde* of the great confluent glaciers. The assemblage of boulders found in both is alike, indicating that the ice during both periods passed over similar rock-masses.

2. The confluent glacier phase, to which belong most of the glacial phenomena exhibited on this map.

At the height of this phase, when the valleys were not sufficient to carry off the ice that emanated from the great centres of distribution and overtopped the watersheds, only a few of the higher summits in the western and south-western part of the region rose as "nunataks" above the widespread surface of the confluent ice-fields. The ice-sheets radiated over the country from two centres of dispersion. The one lay in the south-west and included the high ground that surrounds the Monar basin, the other was formed by the Fannich mountains, a few miles beyond the northern margin of the map. The ice from the former dominated the central and southern, and by far the larger part of the area, the Fannich ice covered the northern marginal portion, the two glaciers being confluent somewhere along the line of Glen Torridon, the Coulin River, Loch a' Chroisg and the south side of Strath Bran.

During the further shrinkage of the ice, other outstanding masses of high ground, such as Beinn Eighe, Liathach, the mountains of the Achnashellach Forest and the Sgùrr a' Mhuilinn *massif* began to assert themselves as independent centres of dispersion, until a series of large glaciers, originating from different snowfields, but still confluent over the lower parts of the intervening ridges, was developed.

At this period the Monar basin, filled with ice from the surrounding mountain ranges, formed a great reservoir which poured its surplus ice-streams through different outlets at different levels as its contents gradually decreased.

3. Valley glaciers.—A further decrease in the thickness of the confluent ice-sheets introduced the third phase of glaciation, when the dividing ridges were no longer covered, and each glen and valley held its own individual glacier. To the last stages of this period, when the ice was retreating up the glens into the high corries, belong most of the more conspicuous features of accumulation: the successive lateral moraines, laid down between the edge of the shrinking glacier and the hillside; the concentric rings of terminal moraines fanning out from the mouths of the corries and often enclosing small lochans; and the deltas and terraces of fluvio-glacial material deposited by the melt-water of the glacier, often in temporary lakes held up by ice or morainic deposits.

This period of retreat is also marked by the numerous ice-groovings and striæ that cover every projecting knob and exposed surface

in the lower parts of the glens and corries, and indicate the local movements of the shrinking ice. Nowhere are these better displayed than in the glens around the head of Loch Torridon and in the Achnashellach Forest, where the deep grooves cut in the glaciated slopes of sandstone seem as fresh as if made but yesterday (Plate V).

Another feature of erosion, in part post-glacial, but probably initiated during the retreat of the ice, is the deep stream-gorges or cañons that cut the lower hill-slopes where the ground was longest free from ice. The melt-water from the retreating ice above would be drawn from a larger area than the catchment-basin of the present stream, and would also supply abundant material for the abrading process.

There is no direct physical evidence in this region of any marked recrudescence of glacial conditions and consequent re-advance of the ice over the country.

The late persistence of glaciers in the corries and short mountain valleys of the western seaboard, where the hills rise abruptly to a great height from sea-level, is proved by the occurrence of moraines, filled with locally derived material, resting upon the 50-ft. beach at the head of Loch Torridon (see p. 102). L. W. H., B. N. P.

THE MONAR BASIN.

The hollow whose lowest portion is occupied by the waters of Loch Monar is surrounded nearly on all sides by lofty mountains, those to the west forming part of the present watershed of Scotland.

The basin is deeply trenched at its eastern end by the hollow through which the Garbh-uisge flows eastward from the loch into Glen Strath Farrar. A subsidiary depression to the south of Loch Monar also drains eastward through the narrow channel of the Uisge Misgeach.

A large branch of the basin—the Glen of Strathmore—extends westward from Loch Monar into the heart of the mountains of the West Monar Forest, and another branch, forming the hollow of the Gead Lochs, extends south-west to Loch Calavie. The latter depression is continuous across the present watershed at Lochan Gobhlach into the valley of the Allt Coire nan Each, whose waters have, as described elsewhere, been stolen from the Farrar basin by the river Ling. The entire basin measures about 10 miles in an east-and-west direction, with a breadth of 6 miles, and must, in glacial times, have formed an ice-reservoir of great capacity, the present surface of Loch Monar being 663 ft. above sea-level, while the rim of the basin, excluding the lower cols, exceeds 2500 ft. in many places, and in the West Monar Forest and the An Riabhachan ridge rises to 3000 and 3500 ft.

Striæ indicating the direction of ice-movement during the maximum glaciation are wanting in the Monar area, all evidence of this nature having been obliterated by the action of frost in late-glacial and post-glacial times.

During the confluent glacier stage the ice accumulated in this great reservoir until it overflowed the rim of the basin in all directions, the Monar region for the time thus becoming a centre of radiating dispersion.

Whether at the maximum extension of this stage of glaciation the ice overtopped the high mountains that enclose the basin there

Coire Làir, Achnashellach. Striated Surfaces of Torridon Sandstone.

is little to show, these higher tops and ridges having been so long subjected to the disintegrating action of frost as to destroy all such records.

But that the ice continued for long periods to envelop the lesser heights up to 2000 ft. is proved by the fresh ice-worn summits of Meallan Buidhe, Meallan Odhar, Beinn Dubh and all the hills of lower elevation within the basin, the deeply scored surfaces indicating the eastward movement of the ice into Glen Strath Farrar. The ice, moreover, passed out over the surrounding cols at elevations of at least 2000 ft.

The highest points of exit are the cols to the north and west of the West Monar Forest, where the ice overflowed the passes at an elevation of 2000 ft. between Bidean an Eòin Deirg and Càrn nam Fiaclan into Gleann Fhiodhaig, and again between Sgùrr Choinnich and Beinn Tharsuinn into Strath Carron. The ice also passed out of the head of the Bealach an Sgoltaidh at a height of 1800 ft. into Coire Seasgach.

In the East Monar Forest the ice crossed the pass into the head of Glen Orrin at an elevation of close upon 2000 ft.

The ice continued to flow out of the south-western part of the basin in a westerly direction for a long period, and at its maximum stage overrode Beinn Dronaig (2612 ft.) and the lesser heights to the south. At later periods it still passed westward through the col at the west end of Loch Calavie at a height of 1200 ft., and by the lower pass to the south of Beinn Dronaig, where the rocks are polished and scored up to a height of 1600 ft.

The main exit, from the Monar basin was, however, to the east, into Glen Strath Farrar—a path followed by the ice long after it had retreated from the higher cols.

Traces of this retreat are found in the moraines left on the watersheds in these passes. A small lochan has been impounded amongst these deposits on the col to the north-east of Bidean an Eòin Deirg.

Successive lateral moraines, whose levels fall *up* the valley, indicate the downward retreat of lobes of the main glacier that were protruded up into these glens long after the ice ceased to escape over the cols.

The fall of the ice-level in the basin is marked by the terminal moraines left on the watershed in the passes, and by the successive lateral moraines that flank the valley sides. The latter indicate pauses in the retreat of the lobes of the main glacier.

When the ice had decreased considerably in volume, the hollows surrounded by the mountains of the West Monar Forest, and those north of the Riabhachan ridge remained as the chief centres of dispersion. The glacier which continued for a time to occupy Strathmore and the hollow of Loch Monar issued in two streams which diverged round Beinn Dubh an Iaruinn, following the course of the present channels of the Garbh-uisge and the Uisge Misgeach into Glen Strath Farrar. The divergent paths of the ice are clearly marked by striæ up to the 1500-ft. contour.

At this time the ice from the West Monar Forest was still pushing a lobe up into the hollow of the Gead Lochs, where it has left numerous lateral moraines on the hillsides. It also deposited part of the immense mass of terminal moraines on the watershed around Lochan Gobhlach, but with these are also mingled the terminal

moraines from a glacier which still occupied the hollow of the Allt Coire nan Each.

These moraines served later to divert the waters of this stream into the drainage-basin of the Ling. At this stage, no doubt, of the retreat, were eroded the deep rock gorges south of Beinn Dronaig in which now run the tributaries of the river Ling. The formation of these gorges in the Carron region, where they are better developed, is attributed by Dr. Peach to glacial drainage during the retreat of the greater glaciers. Such gorges are absent in the Monar basin from the areas occupied by ice to a later period, but the erosion of the small gorges of the Garbh-uisge and the Uisge Misgeach may probably be ascribed in part to glacial drainage during the later stages of retreat.

We now come to the phase of high-level corrie glaciers which marks the latest stage in the history of glacial erosion.

There is evidence of the existence of seven such glaciers in the Monar region. Three of these occupied the large cirques on the north face of An Riabhachan, the other four filled respectively the corrie on the east face of Sgùrr na Lapaich; the hollow drained by the Allt a' Chreachail Mhòir, south of Loch Cruoshie; the corries of the Bealach an Sgoltaidh; and the great cirque on the south side of Meall Mòr.

The furthest extent of these corrie glaciers is frequently marked by the removal of the previously deposited lateral moraines from the area on which the glacier deployed, and by the presence, in their place, of a great spread of hummocky moraines and conical piles of huge blocks of local derivation. A fine example of the latter phenomenon occurs on the slopes about a mile from the large cirques at the west end of An Riabhachan. The floors of these cirques are of polished rock, with striæ directed towards the exit, and large "scree-moraines" lie at their mouths, or, in some cases, well within the retaining walls.

In the largest corrie between Sgùrr na Lapaich and Meall Garbh, blocks occur in positions on the uneven floor that they could only have reached by rolling at times when a great mass of snow and ice extended from the back wall of the corrie. The base of this wall is glaciated and projects beyond the weathered cliff above.

The floor of the great corrie between Sgùrr na Lapaich and Meall Garbh holds two tarns which probably to a large extent occupy a rock basin; for although they are separated by a moraine which also extends beyond their points of exit, rock is found in the burns close to the lip of each loch.

Trails of boulders of garnetiferous mica-schist and Lewisian hornblende-gneiss are common in the Monar district, but the parent rocks are so widely distributed in this region that, except in the case of the corrie glaciers, such evidence is of little importance compared with that afforded by direction of striæ and orientation of moraines.

Drift of a morainic character is widely distributed over the bottoms and sides of the hollows, but nowhere appears to be of great thickness; the greatest accumulation is found on the watershed between Loch Cruoshie and the Gead Lochs. On the flanks of the

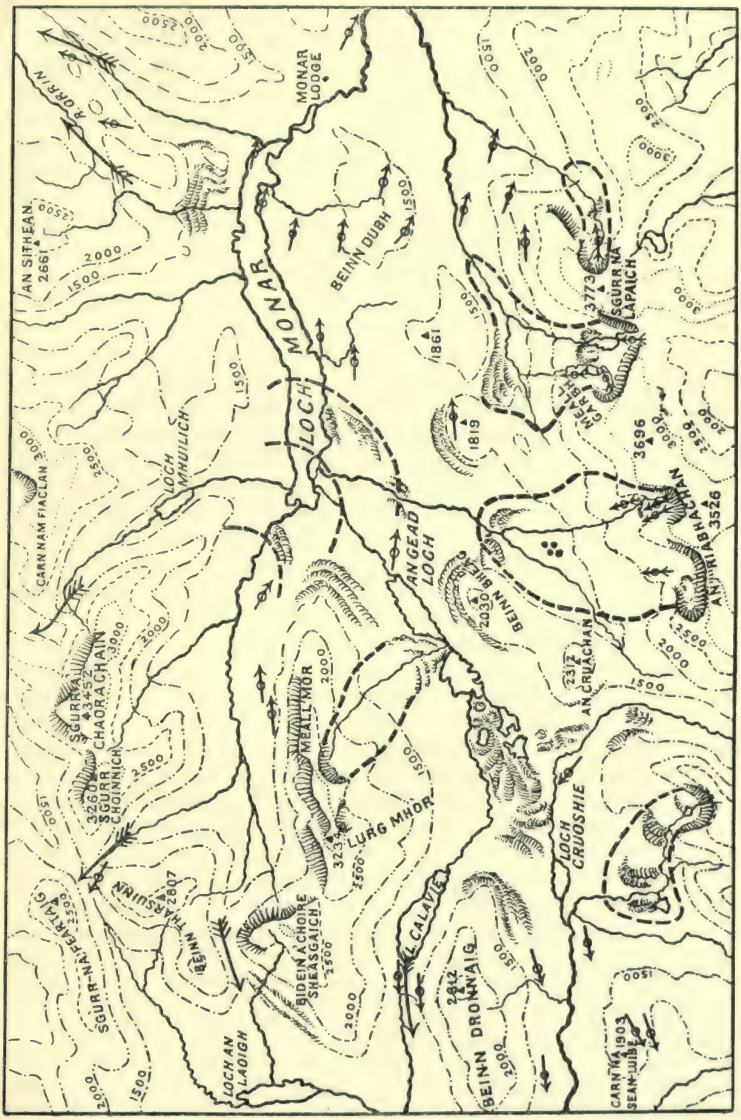

FIG. 10.—Map illustrating the Glaciation of the Monar Basin.

hills it is chiefly represented by the lateral moraines left during the early stages of retreat of the great glaciers.

The Frost Debris of the High Mountain Plateaux.—It has already been stated that on the higher mountain-tops all traces of the ice movements in this region have been obliterated. This is no doubt due to the comparatively early emergence of these summits from the ice-cap, and their prolonged exposure to frost. All the flatter tops at elevations above 3000 ft. are buried in disintegrated rock, the result of this long-continued weathering.*

The high tops which appeared as nunataks at the first shrinkage of the ice, are represented only by narrow ridges in the Monar country, but elsewhere† they often form plateaux of considerable extent. In all cases they present the same great accumulation of frost debris. The wind sweeping across these exposed summits constantly carries away the finer material resulting from weathering, leaving a surface characterised by small angular fragments in the case of siliceous rocks, and by somewhat rounded flattened stones where more pelitic mica-schists form the underlying rock. The debris is frequently many feet in depth, and all the water precipitated on the porous surface layers rapidly finds its way below. The water thus accumulated in the lower layers of disintegrating rock flows along the junction of the debris with the solid rock and issues in springs where the gradient becomes steeper. One of the most striking phenomena of these tops is the manner in which the various bands of mica-schist and siliceous schist are mapped out on the surface by bands of corresponding debris, the material having evidently undergone no displacement. Where, however, the ground begins to slope, the material is effected by earth-creep and assumes a parallel terrace-like arrangement. The general surface of the debris is in all cases very smooth and flattened, owing partly to the action of the wind and the pressure of the winter snows, and partly to the natural adjustment and settling of the material.

This frost debris of the higher mountain plateaux has a very wide distribution in the northern Highlands and exerts a profound influence on the vegetation.‡ The excessive drought induced by its porous nature and exposure to strong winds only allows of a meagre flora of such alpines as are specially protected by devices preventing excessive transpiration, and mosses which can undergo desiccation without permanent injury. Shrubs which in more protected localities assume an erect position form prostrate mats, and even the few species of grasses have prostrate flowering shoots.

The debris is subject to slow removal by the wind carrying away all the smaller particles, but the surface as a whole is little affected by water-erosion, owing to the porous nature of the material.

* The obliteration of the signs of glaciation by the action of frost on the higher summit ridges of the Cuillins is referred to by A. Harker, "Ice Erosion in the Cuillin Hills, Skye," *Trans. Roy. Soc. Edin.*, 1901, vol. xl. p. 229.

† The character and distribution of this mountain-top debris is further described in the Memoir accompanying Sheet 93, also in a forthcoming memoir on Caithness (Sheets 110, 116).

‡ For an account of the vegetation of these debris-strewn summits in Caithness, see C. B. Crampton, "The Vegetation of Caithness Considered in Relation to the Geology." *Published under the auspices of the Committee for the Survey and Study of British Vegetation*, 1911.

High-level Corries.—The northern faces of the higher mountains present lines of precipitous cliff and corrie-wall that contrast with the smooth debris-covered summits above. Corries with a southern aspect are less frequent, and they are not on so grand a scale.* These corries were, in all probability, continuously occupied by ice until the latest phases of the glacial epoch, which prevented the accumulation of the loose material arising from the disintegration of their walls.

In considering the origin of these cliffs and cirques one cannot but be struck by their prevailing northern aspect and by the extent to which they have been eroded back into the summit ridge. When the ice retreated from the mountain-tops, leaving them exposed to the action of frost, the disintegrated rock accumulated on the flatter surfaces. As the ice retreated farther and the steeper slopes became exposed, the loose material on the slopes would be removed by gravitation and by the action of water percolating through the debris and breaking out in springs. Fresh rock surfaces would thus be continually exposed to the influences of frost while the loosened rock would be as continually removed by the glaciers, the greatest removal of rock taking place at those points where the springs were most active, and where the glaciers persisted until the latest phase of the glaciation of the country.

The origin of the high-level hanging corries, even of those most lately occupied by the ice, dates back possibly to an earlier phase of the glaciation. The later retreat of the back-wall of the corrie, in some cases nearly to the waterparting, seems, however, to have been an effect of lateral rather than of vertical erosion, and due to the disintegrating effects of springs and frost, together with the removal of the loose material by the corrie glacier; a process which was continued after ice-erosion had ceased in the main valley below.

The rocky walls of these corries are usually very fresh, and little or no degradation of the face or scree formation has taken place. The loose blocks are probably carried some distance out from the wall by rolling down the snow-slopes that accumulate against the cliff face in the winter-time. The whole aspect of some of these corries indeed conveys the impression of their comparatively late occupation by ice. C. B. C.

THE CENTRAL BELT—STRATH CARRON AND STRATH BRAN.

In the area west of the Monar region the ice-streams which passed westwards through the passes and lower cols of the range that separates that basin from the valleys of the Carron and the Ling became confluent in the wide, shallow, upper valley of the latter stream, and at first filled it to overflowing. A large body of this ice followed the south-westerly direction of the valley, and became tributary to the Loch Alsh glacier, as described in the Explanation of Sheet 71. Another portion of the Ling valley-glacier passed over into the head of Gleann Udalain, east of Strome Ferry, but the larger

* See also A. Harker, *op. cit.* p. 240, and Willard D. Johnson, "The Profile of Maturity in Alpine Glacial Erosion," *Journal of Geology*, Chicago 1904, vol. xii. p. 569.

volume crossed the dividing ridge between the Ling and Carron valleys at as high a level as 1750 ft. Striæ on the waterparting of the Ling and Attadale Rivers, at a height of 1000 to 1250 ft., also indicate a local north-westerly movement; others on the higher ridge between Loch an Laoigh and the Eas an Teampuill point between west-south-west and west-north-west.

After surmounting the dividing ridges the ice merged gradually into the Strath Carron glacier, which, as shown by the striæ, moved west-south-west in the direction of that valley. At this stage no terminal moraines would be laid down in the area under consideration. They are to be looked for to the westward in Loch Alsh, Gleann Udalain, and near the mouth of Loch Carron (Expl. Sheet 71, p. 163).

At the same period the ice streaming northwards out of the Monar cauldron through the high passes at the head of Allt a' Chonais into Glen Carron, met that coming from the mountains to the west and north of Achnashellach, and so choked up the narrow valley that the combined ice-streams could not all escape south-westwards down Strath Carron. A large part of this glacier was therefore forced up Glen Carron and over the present watershed into Strath Bran, gaining volume on its way by tributary ice-streams from the corries of Moruisg and the head of Gleann Fhiodhaig on the south, and from Coire Crubaidh on the north-west.

In the neighbourhood of Achnasheen the glacier coalesced with the ice from the Fannich mountains in the north (Sheet 92), one stream from that source passing down the Allt Duchairidh glen into the hollow of Loch a' Chroisg, the other crossing the hill into the Bran valley at Dosmuckeran.

This great confluent glacier now passed eastwards beyond the limits of this map, sweeping round the flanks of the Sgùrr a Mhuilinn massif and partly overflowing into Strathconon, its path being clearly indicated by the eastward carry of blocks of coarse pelitic gneiss.

The terminal moraines of this eastward moving glacier must again be looked for beyond the limits of our area. They are to be found at the mouth of Strathconon, on the Black Isle, and along the shores of the Cromarty Firth.* Some of the higher terraced moraines on Moruisg, and on the hills immediately to the north of Achnasheen, may represent the upper limits of the ice at this period.

The traces of its retreat are found everywhere along its path, but are too many and varied to be enumerated in detail within the limits of this Memoir. Attention may, however, be called to the terraced lateral moraines on the northern flanks of Sgùrr a' Mhuilinn, from a height of 1750 ft. downwards, and to a similar series of well-marked terraces on the hillsides above Achnasheen and Loch a' Chroisg.

Similar traces of the retreat of the Glen Carron branch of the eastward moving ice are found on the north-west slopes of Moruisg and Sgùrr nan Ceannaichean from the 2000-ft. contour-line downwards, and are equally well displayed on the flanks of Beinn na Feusaige, on the opposite side of the glen.

But perhaps the most striking monument of retrogression is seen at the point where the ice-streams from Monar and Glen Fhiodhaig,

* "Summary of Progress for 1898," *Mem. Geol. Survey*, 1899, p 175.

pouring into Glen Carron, diverged to east and west around Meall an Fhliuchaird. This isolated hill, which rises from the floor of Glen Carron to a height of 1300 ft., is encircled from top to bottom with successive terraced, lateral moraines, while on its very summit lies a small lochan surrounded by a moraine. The spur on the opposite side of the glen, between Allt Coire Crubaidh and the Carron, is featured in a similar fashion.

The retreat of the south-western branch of the confluent ice-sheet is equally well marked by nearly horizontal terraced moraines along the great escarpment slopes that bound the valley of the Ling on the east from Beinn Tharsuinn to Beinn Dronaig.

A later phase of the decreasing confluent ice-sheet ensued when the glacier broke up into lobes which terminated within the area represented in this map. One such lobe, emanating from the Monar basin, filled the upper valley of the Ling, but was unable to surmount its western divide. To the intermittent retreat of this lobe is due the magnificent system of terminal and lateral moraines that floor the wide, flat valley, and hold up the waters of Loch an Laoigh and other smaller lakelets.

Another tongue of ice, partly supplied from the Monar cauldron through the north-west passes, filled the lower valley of the Carron and the Allt Coire Taodail Glen. That the main source of this glacier was, however, the mountains of the Achnashellach and Coulin Forests on the north-west side of the Carron, is proved by the distribution of Torridonian and Cambrian boulders on the southern side of the valley opposite Craig and Lair, and in the Eas an Teampuill, south-east of Strathcarron station.

At this period the glacier must have terminated somewhere in the present position of the head of Loch Carron, and possibly deposited the moraines seen on the low ground at Lochcarron village, and between Attadale and Achintee.

Later still, at the 50-ft. raised-beach period, the position of the snout of the glacier is represented by the great terminal moraine strewn with large boulders of Torridon Sandstone which stretches across the Carron valley and forms a conspicuous feature about a mile and a quarter above Strathcarron station. The section cut through this moraine by the river shows the morainic material overlying boulder-clay, while to the westward the former passes into the well-rounded raised-beach deposits now thickly covered with peat. On the north side of the valley the corresponding lateral moraine extends for several hundred feet up the steep slope of Cnoc na h-Àtha, showing that the Coulags glen contributed its share to the glacier, while on the south side a similar moraine, sprinkled with Torridonian blocks, can be traced along the steep slope with a rising gradient, until at Arineckaig, 3 miles up the glen, it has reached a height of 900 ft. above sea-level.

The further retreat of this glacier up the Carron valley is marked by the moraines enclosing small lochans, that strew the flat bottom of the glen. These are flanked, at a higher level, by terraces of fluvio-glacial gravel laid down between the shrinking ice and the hillsides. These deposits extend as far as the foot of Loch Dùghaill, whose waters they help to retain, although the loch is doubtless, in the main, a rock basin.

About this same period another lobe of ice was protruded from the north through the hollow of the Amhainn Bhuachaig, locally known as the Tullich Glen, 2 miles N.N.E. of Lochcarron village. The terminal moraines merge into the 50-ft. beach at Tullich Farm, and successive concentric crescents on either side of the glen indicate the further shrinking of the lobe.

The history of the lobe-period of the eastern-flowing part of the confluent glacier can be followed in the same manner. Thus the well-known Achnasheen terraces, described in the sequel, were formed in a lake enclosed between the extremities of retreating lobes of ice protruded into the Bran valley from the Monar and Fannich glaciers. So also the lateral moraines which cross the river Bran about 2 miles east of Achnasheen, cutting obliquely across the terraced moraines laid down by the eastward moving glacier of an earlier phase, mark the upper limits of the eastern lobe of the Fannich ice-sheet.

At the same time the western lobe from the same source filled, and terminated near the end of, the hollow of Loch a' Chroisg, while the front of the Glen Carron lobe rested a little to the N.E. of Loch Gowan.

Successive concentric lines of moraines mark the retreat of these lobes into the valleys and tributary glens until only the corrie glaciers of the high mountain masses remained. A small corrie glacier that must for a time have hung down out of the flat hanging corrie between Creagan nan Laogh and Sàil an Tuim Bhàin, just north of Achnasheen, has left its traces in the concentric lines of horseshoe-shaped mounds that loop down the hillside below the corrie mouth, cutting through the parallel lateral moraines of the valley glacier.

Lochs Cnoc na Mòinteich and Coireag nam Mang, on the north side of Moruisg, are good examples of corrie lochans. They are partly rock-basins and partly moraine-dammed, and occupy the last places of retreat of the locally derived ice of the Strath Bran glacier.

So recent is the disappearance of the ice from the higher ground in this region that the streams have done little appreciable work, either in cutting through the morainic deposits or in silting-up the rock-basins.

Lowering of Cols and Over-deepening of Valleys.—It is evident that the long-continued movement of great masses of ice over the area, indicated by the phenomena already described, must have necessitated a large amount of abrasion of the underlying floor, and it is equally apparent that this ice-erosion must have been partial and selective in its action.

The obsequent character of the westward flowing streams in their upper courses, and their appropriation of the headwaters of many of the eastward consequent rivers, have been already pointed out in Chapter I. The fact that during the earlier phases of the glaciation the chief ice-sheds lay to the east of the present water-shed has also been referred to.

The concentration of the ice upon the cols along the divides caused a more rapid movement of the glaciers at these points, with a consequent greater abrasion and lowering of gradient in the upper

reaches of the eastward flowing streams. The existence of lakes, either in rock-basins or held up by moraines near to, or actually upon, the watersheds is due to the same cause.

The upper part of the Carron valley, where, during the confluent-glacier phase, the ice moved from west to east, seems at first sight an exceptional case. During the maximum period of glaciation, however, the ice must have flowed in the contrary direction. The gradient on either side of the present watershed is, moreover, very slight, and if the alluvial fan which now forms the divide were removed, would be still less. B. N. P.

Similar phenomena have been observed in the Monar area, where the prolonged flow of ice through the gaps in the rim of the basin has in a marked degree affected the gradients of the higher parts of the valleys leading up to these cols, and has given to the latter a broad trough-like character.

The floors of the cols are usually formed of glaciated rock, but where the flat portion of the pass is of considerable extent it is often peat-covered, owing to insufficient drainage.

An example of a lake situated upon the watershed is found in Loch Mhoicean, which lies just beyond the southern limit of the map, on the flat watershed between the valley drained by the Allt Coire nan Each and Glen Elchaig. The pass between Coire na Sorna and the head of Loch Calavie is also but slightly higher than the surface-level of that loch. There can be little doubt that the situation of both these lochs is mainly due to the lowering of the grade of the valley heads and passes by the long-continued outflow of ice from the Monar reservoir. It would indeed seem that concurrently with the deepening of the main depressions of the Monar area and oversteepening of their sides, the ice moving outwards up the higher parts of the valleys and through the cols, caused a lessening in the original gradient and a steepening of their walls.

On the farther side of the cols, beyond the rim of the basin, a reverse action has taken place, and the gradients have been steepened by the increased volume of ice passing down the valley. C. B. C.

The position of the earlier ice-sheds also accounts in some measure for the excessive over-deepening of the western valleys, through which a much greater volume of ice was made to pass than would have fallen to their share had the ice-shed coincided with the present waterparting.

The valley of the Carron below the mouth of Glen Carron is a typical valley of glacial erosion, over-deepened and out of harmony with its tributaries, and with the side spurs all removed. The valley of the lower Ling is equally well ice-moulded and over-deepened, especially just beyond the confines of the present map.

Rock-Basins.—The waters of Loch Sgamhain occupy an important rock-basin in the Glen Carron district. This loch has at one time had a much greater extent, but its lower end has been silted up for a distance of more than a mile by the Allt Coire Crubaidh, while its sides and upper end are much encroached upon by morainic deposits and alluvial cones.

Loch Dùghaill is probably a rock-basin, as its bottom is below sea-level, while the rock is seen in the river Carron about $\frac{1}{3}$ mile

below its outlet. Loch an Laoigh may also be regarded as a rock-basin, although the present level of its waters is due to a retaining barrier of moraine material. Many smaller rock-basins are scattered over the low plateau that forms the watershed between the Ling and the Lower Carron. Of these the largest are Loch an Iasaich, south-east of Attadale, and Lochs nan Creadha and Chàirn Bhàin above Achintee.

Their origin as ice-eroded hollows is evident from their positions, near, or actually upon, the watershed; as in the instance of the Lochan Fuara, by the side of the road from Attadale to Ben Dronaig Lodge.

Glacial and Post-glacial Rock Gorges.—Numerous gorges occur in this region, which is eminently favourable to the production of these features of erosion. They have been almost exclusively developed in areas where the ice, having already helped to prepare a steep gradient, was in the course of retreat.

The work of erosion was evidently greatly accelerated by the volume of melt-water derived from extensive ice-fields that crossed more than one of the present watersheds, and also by the graving-tools provided by the abundant moraine detritus delivered by the glaciers and swept down the streams.

On the steep, over-deepened, south-eastern slope of the Carron valley and Loch Carron, nearly every tributary stream falls from the plateau above through a cañon-like gorge. Typical examples of these gorges are seen on the streams that fall into Loch Carron at Imair and Ardnarff, and along the course of the Eas an Teampuill Burn, east of Strath Carron station. The Carron flows for more than a mile below Glen Carron Lodge through a deep gorge, and similar features are found on the Allt a' Chonais, the situation of the gorge being in each case due to the over-deepening of the valley at this point. Above the gorges the streams are flowing over the alluvial deposits of silted-up glacial lochs. In the last of these examples the flaggy, jointed Moine schists, dipping up-stream, specially lend themselves to the production of these deep, narrow, vertically walled cañons, with waterfalls towards their head.

On the northern side of the valley the gorges cut by the river Làir and other streams are not so pronounced; the volume of water flowing down the slopes on this side, being probably derived only from local glaciers, would be much less than that on the south slope.

B. N. P.

VALLEY OF THE RIVER MEIG.

Few traces of the early glaciation remain between the Meig valley and Loch Monar. North of Creag na h-Iolaire, and again to the east of Càrn Gorm, quartz veins striated in a north-easterly direction were observed, but on the whole striæ are rare on the hill-tops, the rock-surfaces being too much weathered.

Of the later or valley glaciation there is abundant evidence. Terminal moraines can be seen throughout the length of the Upper Meig valley and especially in Gleann Fhiodhaig, ¾ mile above Allt na Criche. One or two peculiar rock-types also afford boulder trails that can be traced for considerable distances. For example, boulders derived from a zoisite band with small idiomorphic garnets

GLEANN MÉINICH. GLACIALLY DEEPENED VALLEY SHOWING LATERAL AND TERMINAL MORAINES.

in the pelitic gneiss of Creag Dhubh Mhòr, can be followed continuously for over two miles down the south side of the valley.

Hanging valleys are conspicuous at the head of Gleann Fhiodhaig. The large corrie on the north-west face of Maoile Lunndaidh and Srath Mhuilich, further south, furnish good instances of this phenomenon. In both of these cases rock-basins are found behind the lip of the valley. Other lochs in the district, however, are drift-dammed. Of these, Loch a' Chlaidheimh is the best example.

R. G. C.

The protrusion of a tongue of ice from the great confluent glacier of Glen Carron and Strath Bran in a south-easterly direction through the hollow at the head of Loch Beannacharain, is indicated by the numerous boulders of basic rock from Coir' a' Bhuic and Càrn Mhàrtuin that strew the pass between Scardroy Lodge and the watershed. The retreat of this lobe is also well marked by the series of concentric moraines that fill the hollow of Coir' a' Bhuic, and the lateral moraines along the lower slopes of Leanaidh.

One of the finest lateral moraines in the region flanks the steep southern side of Gleann Mèinich, the deep and narrow valley that separates Meall na Faochaig and Sgùrr a' Mhuilinn. It is evident that this remarkable glen has been occupied by a powerful body of ice that in its earlier stages had more than a local origin, and passed eastwards, as a lobe from the main Strath Bran glacier, through the depression in the watershed at the head of the glen.

The hanging valleys out of which the torrents from Sgùrr a' Mhuilinn fall steeply into the glen, and the magnificently glaciated rock-face of the truncated spur of Creag Ghlas, represent an amount of over-deepening greater than could possibly have been executed by a glacier fed by the snow-fields of Sgùrr a' Mhuilinn alone.

The lateral moraine referred to above forms a conspicuous feature for about a mile in the upper part of the glen, and a retreat moraine, well seen in the accompanying plate (Plate VI.), crosses the valley just above the shepherd's house. The moraines that sweep round the shoulder of Meall na Faochaig into the Meig valley, and the corresponding features at the mouth of the glen on the other side, were probably laid down at a later period by the valley glacier.

The phenomena of the later valley-glacier phase, when the ice-movement coincided in direction with the trend of the valleys, are apparent along the course of the Meig in the numerous easterly striæ on the lower slopes of the glen, and the lateral moraines that girdle the hillsides on either side of the hollow of Loch Beannacharain.

It was probably at this period that the mass of gravelly morainic material that partially holds up the waters of that loch was laid down at the confluence of Gleann Chorainn with the main valley. The coincidence of the former with the shatter-belt of the Strathconon fault would conduce to excessive glacial erosion, with a corresponding large discharge of detritus at the valley-foot.

GLEN ORRIN.

It has already been pointed out that during one phase of the glaciation of the country, the ice that filled the Monar basin found

relief through the passes at the heads of Glen Orrin and Coire Dhomhain. The path of the ice north-eastwards into Glen Orrin is marked by the morainic deposits that cover the floor and sides of the pass across the watershed, at a height of over 2000 ft., and by the glaciated surfaces at the head of Coire Dhomhain, showing where the ice poured in a steep ice-fall down into the Orrin valley.

The vertical range of the Monar ice-stream in the higher part of the Orrin glen at different periods is indicated by the fine series of lateral moraines that flank the main valley and sweep up, with a convex outline, into the tributary glens.

Further down Glen Orrin, the glacier, reinforced by the ice pouring out of the northern corries of the Sgùrr a' Choire Ghlais range, filled the expanding valley up to at least the 2000-ft. contour-line; the retreat of the ice from that level is well marked by the successive terraced moraines that flank the southern slopes of the valley. On the north side, the finely glaciated surfaces on the hill-slope above the foot of Loch na Caoidhe, show that the ice was at one time thick enough to over-ride the ridge between that loch and Gleann Chorainn.

The upper part of Glen Orrin, above Am Fiar-loch, presents a good example of an over-deepened valley in which the tributary burns are not in harmonious adjustment with the main stream. Each of the small streams on the north side falls steeply from the mouth of an abruptly truncated hanging corrie, and the larger burn, Allt Loch a' Ghormlaich, descends in the lower part of its course to the main valley over a series of waterfalls.

Another instance of a hanging valley which, though not in Glen Orrin, may be quoted here, is that of the stream 1 mile E.N.E. of Inverchoran, which pours out of a flat valley down the steep side of the Meig glen in a cascade several hundred feet in height. The excessive ice-erosion in the valleys of the upper Orrin and the Meig below Inverchoran is no doubt largely due to their coincidence with the crush-zone of the Strathconon fault.

Corrie Lochans.—A good example of a loch occupying a hollow entirely due to glacial erosion, is afforded by An Gorm-Loch, on the south side of Glen Orrin. At the head of this loch, bare glaciated surfaces plunge steeply down into deep water, while at the lower end the water escapes over a rock lip.

Smaller corrie tarns, partly moraine-dammed and partly rock basins, lie on the floors of the northern cirques of Sgùrr Fhuar-thuill. On the further side of the Farrar-Cannich watershed the waters of Loch Tuill Bhearnach fill a rock-basin in the deep south-eastern corrie of Sgùrr na Lapaich and are also partially held up by the moraine of the corrie glacier. Loch a' Choire Bhig, a little further to the south, lies in a hollow excavated in the rock-floor of the fine hanging cirque on the eastern face of Bràigh a' Choire Bhig.

L. W. H.

GLEN STRATH FARRAR AND GLEN CANNICH.

The direction of glacial striæ between Càrn Eiteige and the south side of the Garbh-uisge indicates a movement across that part of the Monar area of from 20° to 35° south of east. Further to the south they point nearly due east, while others to the east of Creag

Dhubh show that the ice at one time passed out of Glen Cannich in an E.N.E. direction across the watershed. A contrary movement at another period, from Glen Strath Farrar into Glen Cannich, is suggested by cross-striæ found on the south side of Toll Odhar Mòr, and others pointing south-east on the summit of Mullach Tarsuinn. Most of the above phenomena may be referred to the second or confluent-glacier phase of the glacial period.

Evidence of a later stage of glaciation is afforded by the well-marked lateral moraine which runs for about a mile along the south-east side of the Garbh-choire. Another conspicuous moraine crosses the head waters of the Allt Innis a' Mhuilt to the south-east of Càrn nam Fiacal, and is probably the lateral moraine of a glacier that occupied the Farrar valley. Both these moraines lie somewhat below the 2000-ft. contour. Less marked morainic features extend almost up to the watershed on the southern side of Glen Strath Farrar, while the smaller moraines are abundant on both sides of the valley on certain parts of the lower slopes, and practically descend to the level of the river.

The hollow running south-east from Loch Bad na h-Achlaise is at its highest point only about 40 ft. above the level of Loch Monar, and has evidently been eroded by the outflow from the lake-basin. After the water had once made a channel for itself along this course, it is difficult to see what could have diverted it except the agency of ice. The gorge of the Garbh-uisge is therefore possibly later than part of the glacial period, and its steep slopes with abrupt upper margins give it all the appearance of having been recently eroded. If this is admitted, the fact that the gorge is glaciated almost down to stream level would seem to furnish proof of at least a local re-advance of the ice.

Another striking fact is the very small amount of erosion effected by this stream and the Allt Toll a' Mhuic in the lower parts of their courses, although higher up they have both cut deep gorges. The gradient, being steep in both cases, does not afford an explanation, which may possibly be found in the occupation of the valley of the Uisge Misgeach by a glacier which wore away the whole surface of the ground in this locality long after the Garbh-uisge had begun to cut its course. The facts may be taken as showing how very recent, comparatively speaking, was the last phase of glaciation in this part of Scotland.

The alluvial plain which extends down the valley of the Farrar for about a mile below Inchvuilt is still often flooded in winter, and occupies the site of an earlier loch. At its lower end a rock barrier, now breached by the Farrar, extends across the valley, and the hollow evidently represents a waste-filled rock-basin eroded in glacial times. Two dry channels cross the rock barrier to the north of the present outlet. The more southerly is faint; it has been followed by the road which goes up the glen. The other forms a very distinct hollow known as the Dubh-ghlac, and has probably been eroded along a line of fault. These dry valleys must have been formed when the present outlet was covered in some manner by ice. E. M. A.

AREA WEST OF STRATHCARRON AND GLEN DOCHERTY.

Abundant evidence as to the direction of the ice-movement during different phases of the glaciation of the country is afforded by the striæ observed on the bare summits and hill-slopes of the Achnashellach, Coulin and Torridon Forests.

The striæ found on the top of An Ruadh-stac at 2919 ft., pointing W. 25 N.; on Sgùrr Dubh at 2560 ft.,—W. 5–10 N.; and on the eastern peak of Beinn Liath Mhòr above 2500 ft.,—N. 42 W. are, as already suggested, referable to the maximum glaciation, when the ice-sheet moved westwards over the highest mountain tops. Numerous other ice-markings with a general direction between W. 5 S. and W. 35 N., indicate a similar movement, but may belong to a slightly later period. Many of these last-mentioned striated surfaces are crossed by later striæ, pointing in various directions but always more or less down into the valleys. Cross-striæ are particularly abundant to the south of An Ruadh-stac, round the head of the Tullich Glen. The earlier markings here point W. 10 S., the later S.W.–S. 10 E. down the glen. Others are seen at the head of the pass west of Loch an Eoin, the earlier pointing W. 30 N. over Beinn na h-Eaglaise, the later N. 10 E. down into Gleann Thràil. Other low-level striæ running more or less in a reverse direction to that of the earlier ice-movements are found in the hollow between Beinn Eighe and Liathach (east); in Gleann Thràil; in Allt Coire Beinn Léithe in the Coulin Forest (E. 5°–25° N.); in Coire Làir, Achnashellach (S. 10 E.–S. 8 W.) and on the lower slopes of Strath Carron (S.W.). All these belong to the later phases of valley glaciation when the local ice-sheds were practically coincident with the present minor water-partings.

Erratic Blocks.—Fragments of Moine schist that have obviously been carried westwards across the Carron valley occur up to a level of 2900 ft. on the south-eastern slope of Sgòrr Ruadh (3142), and are abundant at a height of 1500–1750 ft. on An Ruadh-stac, and on the Bealach na Lice, the pass between Coire Fionnaraich and Glen Torridon. The bare sandstone summit of Maol Chean-dearg (3060) is strewn with blocks of Cambrian "pipe-rock" that must also have travelled a certain distance from the east. L. W. H.

Similar evidence is obtained in the area to the west of the Kinlochewe River and in the Coulin Forest. On the ridge of Beinn Eighe N.N.W. from Loch Clair, debris of granulitic quartzose schist of the Moine Series occurs at a height of 2250 ft. Near the crest of the watershed about three-quarters of a mile south from Sgùrr Dubh, blocks of Moine gneiss have been recorded about the 1500-ft. level, and a boulder of garnetiferous muscovite-biotite-schist at an elevation of 2000 ft. on Beinn Liath Bheag. These materials have been transported across the depression that stretches northwards from Loch Coulin to Kinlochewe. J. H.

Boulder Clay.—The scouring effect of the later glaciation is very marked in the north-western region, where almost every trace of ground moraine that might be attributed to the earlier ice-sheet has

been removed. A few small patches of boulder-clay cling here and there to the higher hill-slopes and the heads of the valleys.

L. W. H.

Sections of boulder-clay are to be found in the Coulin Forest where the material underlies the valley moraines. These sections occur at the head of the east branch of Allt na Lùib which flows into Loch Clair, the locality being about a mile distant from Coulin Lodge in a S.S.W. direction. The deposit consists of stiff, stony clay, with well striated stones, and, though resting on Cambrian strata, contains numerous blocks of granulitic schists of the Moine Series, thrust Lewisian Gneiss, and displaced Torridon flags and sandstones. These are the best recorded instances in the eastern portions of the Beinn Eighe and Coulin Forests. In general the moraines rest directly on the underlying rocks. J. H.

Moraines.—In the north-western area the morainic drift belongs partly to the period of confluent glaciers, partly to that of the later valley glaciers and partly to the time when the ice had shrunk into the high corries.

The moraines resting on the plateau of Moine schists between Féith an Leothaid and Càrn Breac were probably deposited during the confluent glacier period when the ice moved in a westerly direction. The materials were derived from the platform of crystalline schists east of the Moine thrust. The main channel of escape at this stage was down Glen Torridon, as shown by the abundance of Moine schist debris in the moraines in that valley and high up on the slopes of Beinn Eighe and Sgùrr Dubh, where they rest on a floor composed mainly of Torridon Sandstone. Further south about two miles S.S.W. of Loch Coulin and about half a mile to the west of Allt nan Dearcag, at the level of 1200 ft., fragments of Moine schist are plentiful in the moraines resting on the Cambrian quartzite.

The deposits laid down by the local glaciers radiating from the heights in the Coulin Forest are well developed in the hollow between Beinn Liath Mhòr and Beinn Liath Bheag, and along the eastern declivity of this mass of high ground. The easterly movement of these local glaciers is proved not only by the striæ but also by the transport of debris and boulders of Torridon Sandstone eastwards to the low ground south of Cnoc Daimh, where the moraines rest on Cambrian quartzite not far from the outcrop of the Moine thrust. It is further evident that blocks of gneiss originally carried up the valley of Allt Coire Beinne Léithe were borne down the valley at a later date by the local glacier. Boulders of gneiss and Torridon Sandstone rest on the moraines on the south side of this stream at the level of 1000 ft.

The local character of the morainic materials deposited by the later glaciers is also well shown on the slope about half a mile south of Sgùrr Dubh. In the west branch of Allt na Lùib the relation between these accumulations and the underlying strata is clearly exposed. The ground is strewn with moraines, arranged in conical heaps and ridges, composed of loose debris and sand with subangular stones. Several prominent structural lines cross this area in a north-east and south-west direction, which mark the limits of the

parallel strips of the Torridonian and Cambrian strata. Here it was noted that the included blocks in the moraines vary according to the nature of the subjacent rocks. When the latter consist of Torridon Sandstone, the morainic materials are composed chiefly of Torridonian debris, and a similar relation is observable when the rocky floor is paved with Cambrian strata.

An example of a moraine left by a corrie glacier is to be found on the south slope of Sgùrr Bàn below Coir' an Laoigh, where the materials in the mounds consist of basal quartzite and Torridon Sandstone derived from the walls and floor of the corrie. Such an assemblage differs from that occurring in the moraines along the same declivity in which debris of Moine schists is a prominent constituent. J. H.

A remarkable assemblage of hummocky terminal moraines fills the Coir' a' Cheud-chnoic (corrie of the hundred hills) at the head of Glen Torridon, and surrounds Lochan an Iasgaich, marking the retreat of the glaciers that filled the through valley of Glen Torridon and the deep glen of the Coire Dubh (see Plate VII.).

The head of the valley that runs S.S.W. from Loch an Eoin is filled with hummocky drift and moraines strewn with large boulders of locally derived blocks, laid down by the glaciers of Maol Cheandearg and Beinn Damh;—the latter lying just outside this Sheet. Other groups of terminal and lateral moraines, whose arrangement shows that they have been deposited by glaciers moving down the valleys, cover a considerable area in the upper part of Coire Fionnaraich north of Coulags, and in the valley of the River Làir.

LOCH TORRIDON.

The relations of the valley moraines of Gleann Thràil to the 50-ft. raised beach at the head of Loch Torridon point either to the continuance of glacial conditions in the mountains of West Ross up to the comparatively recent period when the shore-line stood 50 ft. higher than at the present time; or to a recrudescence of cold conditions, not necessarily very great, but sufficient to cause the glens and corries of the western sea-board to be once more occupied with glaciers that descended to sea-level.

Immediately below the confluence of the River Torridon and the Abhainn Thràil a fan of well formed circular moraines, pouring out of the valley of the latter stream, has been laid down upon the flat surface of the raised beach. The relations of the two deposits were at one time well exposed in an opening made for road-metal at the roadside leading to Annat, immediately south of the river. The section showed six feet of loose morainic material filled with angular and subangular blocks and smaller fragments of Torridon Sandstone and Cambrian quartzite, resting upon the horizontally-bedded sand and well rolled shingle of the raised beach.

It is important to note that while the material of the moraine can all have been derived from the basin of the Abhainn Thràil, a large proportion of the pebbles in the beach deposit are of Moine schists, and must have come from a region several miles to the east of the existing watershed. This beach-material contains the detritus washed down from the drift deposits of an earlier ice-sheet that

Coir' a' Cheud-chnoic (Corrie of the Hundred Hills). Head of Glen Torridon.
Hummocky Terminal Moraines. Lochan an Iasgaich in foreground, held up by drift and cones of alluvium.

crossed the present watershed; but of whose passage all traces, at lower levels, have been removed by the later valley glacier whose terminal moraines we have just described.* L. W. H.

Fluvio-glacial Gravels.—The traveller on the Dingwall and Skye Railway can hardly fail to notice, shortly after passing Achnasheen Station, the conspicuous features formed by the high-level terraces that extend from the foot of Loch a' Chroisg to a quarter of a mile beyond the railway line (Plate VIII.).

The highest of these terraces forms a wide peat-covered plateau west of the road with a gentle inclination from west to east, the western margin rising 605 above sea-level, or 100 ft. above the present level of Loch a' Chroisg; the eastern margin 570 ft., giving a fall of 35 ft. in nearly half a mile. East of the railway the fall—25 ft. in half a mile—is from S.S.W. to N.N.E. No less than five lower terraces can be traced on the eastern side to the south of Old Ledgowan Lodge. Most of these have probably been carved out of the original deposit by the stream flowing out of Loch Gowan. The sections exposed by the River Bran, which has cut a deep channel through these deposits, and also along the railway between Achnasheen and Loch Gowan, show the lower portion to be composed of finely laminated clayey sand with occasional pebbly bands, obliquely bedded and often lying at a high angle. The upper part of the section consists of a coarse subangular and rounded gravel. In another section, lately exposed near the New Lodge, the laminated sand contains large angular blocks of gneiss lying at different angles.

The surface of the higher plateau shows several of the deep circular depressions or "kettle-holes," so characteristic of the fluvio-glacial deposits. The margin of the higher terrace on the southern side is ill-defined, and seems to merge into the successive lateral moraines which flank the north-eastern face of An Liathanach.

The finer material in the lower part of this terrace—as first pointed out by Dr. Penck of Berlin, during a visit paid to the region under the guidance of Messrs. Peach and Horne in 1895—was laid down as a delta deposit in an ancient lake, and subsequently covered by the coarse fluvio-glacial gravels. This lake appears to have occupied a position between the present foot of Loch a' Chroisg and a point in the Bran valley, a short distance east of Achnasheen. The waters were held up to the east by a lobe of ice protruded westwards up Strath Bran from the Fannich glacier, which moved southwards over the high ridge south of Loch Fannich and sent its main stream eastwards down the Bran valley.†

On the west and south-west of this lake, the valleys in which now lie the waters of Loch a' Chroisg and Loch Gowan were also occupied by ice-streams, in this case moving eastwards. At the retreating ends of these glaciers the material was delivered and laid down, first in the form of fine-grained material at the advancing

* "The Occurrence of Moraines later than the 50-ft. Beach in the North-west Highlands." By Lionel W. Hinxman, B.A. *Trans. Geol. Soc. of Edin.*, vol. vi, 1892, p. 249.

† See also W. Morrison, "Terraces at Achnasheen, Ross-shire." *Trans. Edin. Geol. Soc.*, vol. v, 1888, p. 275. Sir A. Geikie, *The Scenery of Scotland*, 1901, pp. 294, 508.

front of the delta over which the coarser fluvio-glacial gravels were afterwards distributed. B. N. P., L. W. H.

ii. Raised Beach and Recent Deposits.

Raised Beaches.—No remains of the 100-ft. raised beach have been observed in the part of Loch Carron within the present map, although conspicuous terraces occur at that level at Strome Ferry and at the mouth of Srath Ascaig in Sheet 71.*

As already indicated (see p. 92) at the time of the deposition of the 100-ft. beach at Strome Ferry the loch above that point was probably occupied by a lobe of the great confluent glacier, the end of which had retreated to above the head of the loch before the formation of the 50-ft. beach.

Remains of the 50-ft. beach are to be found round the head of Loch Carron. Although this terrace is much obscured by peat as well as by cones of alluvium brought down by side streams, sufficient evidence is left to show that the sea stood for some considerable period at or about this level. The chief evidence is supplied by the presence of spits or storm beaches, which occur on the west side of the loch between Kirkton and the smithy to the north, where they attain a height of over 43 ft. The cuttings in the railway to the north of Strath Carron station show false bedded, well rounded gravels at heights ranging from 38 to over 51 ft. Similar evidence is obtainable from the steep banks of the River Carron. The gravel flat, for the most part peat-covered, gradually rises towards and is bounded by the great terminal moraine that crosses the valley about ¾ mile above New Kelso, which evidently indicates that the glacier protruded into the sea at this point during the deposition of this beach (see p. 93). A similar arrangement of the 50-ft. beach deposits with regard to the moraines emanating from the valley at Tullich, about a mile north of Kirkton, is observable.

The deposits are also found in Attadale for about a mile upwards from its mouth, where they are much covered up with alluvial cones from the side streams.

Along the shores of Loch Carron the 50-ft. beach is chiefly replaced by a rock notch bounded by a cliff drilled with caves. This feature is very conspicuous on the east side of the loch between Achintee and Attadale and from thence to the edge of the map. The village of Lochcarron on the west side of the loch is backed by a similar cliff.

A raised beach about 25 ft. above Ordnance Datum is found at intervals along both sides of Loch Carron. It is well seen between Achintee and Cam-allt and on the west side of the loch the village of Lochcarron is for the most part built upon it. Some of the flats at the head of the loch are doubtless underlain by deposits of this beach. B. N. P.

Beaches at two different levels, with average heights respectively of 25 and 50 ft. above present sea-level, occur at the head of Loch Torridon, on the western margin of the map. The higher beach extends for nearly a mile up Glen Torridon, forming a narrow fringe

* "The Geology of Glenelg, Lochalsh and South-east part of Skye," pp. 163 and 168. *Mem. Geol. Survey*, 1910.

Fluvio-Glacial and Alluvial Terraces. Looking south from near Achnasheen Station.

along the rocky side of the valley, and into the mouth of Glen Thràil where its limits are obscured by the overlying moraines. The contents of this beach and its relation to the moraines have already been discussed (see p. 102). The 25-ft. beach forms the lower cultivated area around The Mains.

The 50-ft. beach is more conspicuously developed further down the loch on either side, a short distance beyond the limits of this Sheet.

Freshwater Alluvium.—The rivers of this mountainous region are for the most part still engaged in grading their courses, and there are consequently but few stretches of alluvial flood-plain within the area. Below Achnasheen the Bran winds for two miles through its earlier alluvial deposits, upon which the tributary streams on either hand are laying down cones of coarser material. A wide stretch of meadow-land fills the bottom of the valley between Dosmuckeran and Loch Achanalt and indicates the former extension of that loch up the valley (see p. 5).

The River Carron in its course from Loch Dùghaill flows through a wide flood-plain which lower down appears to merge into the deposits of the raised beach. The alluvial stretch above the loch represents the material swept down out of the gorge above and the cones of the tributary burns.

The area of alluvium shown on the map at Scardroy, at the head of Loch Beannacharain, marks an earlier flood-plain of the River Meig, when the waters of that stream escaped at a higher level than the present waterfall over the bar of gneiss that here crosses the valley. Below Loch Beannacharain the Meig is cutting through a considerable accumulation of sand and gravel, some of which may be of fluvio-glacial origin, but has been reinforced by the material brought down out of the fault-valley of Gleann Chorainn.

L. W. H.

The alluvial deposits at the western end of Loch Monar indicate the former extension of the loch for fully ¾ mile up Strath More. The head of the loch is being rapidly silted up by the sand brought down by the mountain streams, and the part between Patt and Strathmore Lodge is in dry weather only connected with the main body of water by a narrow channel near the north shore. During easterly gales the sand in the shallow water at the western end is driven further west and forms a sand bar extending from near Patt to the northern shore. The western portion of the loch is thus generally very shallow and weedy, but deep holes occur in places surrounded by weedy growth which shuts out the sediment.

C. B. C.

The alluvial plain through which the River Farrar flows below Inchvuilt has already been referred to as indicating the site of an earlier loch; and the alluvium shown at the head of Loch a' Mhuillidh similarly points to a former extension of that piece of water up the valley.

Other smaller areas of alluvial deposits are found in different parts of the map, and are for the most part due to the junction of the cones laid down by two or more of the mountain torrents. Such are the alluvial stretches at the heads of Glen Torridon, Loch

Coulin, Loch a' Chroisg and Loch Gowan, and in Gleann Fhiodhaig and Glen Orrin. L. W. H.

Peat.—Considerable stretches of high ground in the north-eastern part of the map are occupied by hill-peat of varying depth. The largest unbroken area covers the watershed of the Bran and Meig Rivers between Sgùrr a' Ghlas Leathaid and Càrn Mhàrtuin, where the peat has an average depth of 5 to 7 ft. Other extensive peat-mosses with about the same depth are found on Meall Buidhe south of Loch Beannacharain, and along the north-western slope of the Sgùrr Coire nan Eun range at the head of Glen Orrin. In the former moss different layers containing pine and birch remains have been observed, the pine nearer the top, the birch at or near the base of the deposit. Smaller patches of peat at lower levels in many parts of the area occupy hollows in the drift, and mark the sites of former lochans or of extensions of existing pieces of water. The freshwater and marine terraces in the lower part of Strath Carron are often covered with peat, as are also the higher fluvio-glacial terraces at Achnasheen.

In the Monar area the peat is chiefly confined to the lower ground, and though widely distributed around Loch Monar and the Gead Lochs, is everywhere limited in extent, lying in small hollows between the moraines and on some of the oldest alluvial flats. Only a few small patches were observed above the 1500-ft. contour-line. Pine stumps, often of considerable size, are of common occurrence in the peat of this region.

Some of the most accessible mosses are dug for fuel for local use, but in so thinly populated a country the amount worked is but trifling. L. W. H., C. B. C.

APPENDIX.

LIST OF WORKS RELATING TO THE GEOLOGY OF THE DISTRICT INCLUDED IN SHEET 82.

1844. Nicol, J. Guide to the Geology of Scotland. Edin. and Lond. (Graphite of Glen Strath Farrar), p. 197.

1857. Nicol, J. On the Red Sandstone and Conglomerate and the Superposed Quartz-Rocks, Limestones, and Gneiss of the North-West Coast of Scotland. *Quart. Journ. Geol. Soc.*, vol. xiii. p. 17.

1859. Murchison, Sir R. I. On the Succession of the Older Rocks in the northernmost Counties of Scotland, with some Observations on the Orkney and Shetland Islands. *Quart. Journ. Geol. Soc.*, vol. xv. p. 353. [Abstract in vol. xiv. p. 501.]

1860. Nicol, J. On the Relations of the Gneiss, Red Sandstone, and Quartzite in the North-West Highlands. *Rep. Brit. Assoc.* for 1859, p. 119.

1861. Nicol, J. On the Structure of the North-Western Highlands and the Relations of the Gneiss, Red Sandstone, and Quartzite of Sutherland and Ross-shire. *Quart. Journ. Geol. Soc.*, vol. xvii. p. 85.

1865. Geikie, [Sir] A. The Scenery of Scotland viewed in connection with its Physical Geology. 8vo, Lond. 2nd ed. in 1887; 3rd ed. in 1901.

1878. Home, D. Milne. Fourth Report of Boulder Committee, with Remarks. *Proc. Roy. Soc. Edin.*, vol. ix. [Achnasheen terraces, p. 690.]

1885. Hicks, H. On Some Recent Views concerning the Geology of the North-West Highlands of Scotland. *Proc. Geol. Assoc.*, vol. ix. p. 43.

1886. Lucy W. C. The Terrace Gravels of Achnasheen, Ross-shire. *Proc. Cotteswold Naturalists Club*, vol. viii., pp. 118–120.

1888. Morrison, W. Terraces at Achnasheen, Ross-shire. *Trans. Edin. Geol. Soc.*, vol. v. p. 275.

1893. Hinxman, L. W. On the Occurrence of Moraines later than the 50-foot Beach in the North-West Highlands. *Trans. Edin. Geol. Soc.*, vol. vi. p. 249.

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1905. Teall, J. J. H. [Director]. *Summary of Progress of the Geological Survey for* 1904. [Messrs. Peach, Hinxman, Carruthers, Anderson and Crampton, pp. 74–80, 84, 85.]

1906. Teall, J. J. H. [Director]. *Summary of Progress of the Geological Survey for* 1905. [Messrs. Hinxman, Crampton, Carruthers and Anderson, pp. 103–110, 115, 116; Dr. Flett, Appendix I., pp. 155–167.]

1907. Teall, J. J. H. [Director]. *Summary of Progress of the Geological Survey for* 1906. [Messrs. Hinxman, Crampton and Anderson, pp. 81–85, 87.]

1907. Peach, B. N., Horne, J., and others. The Geological Structure of the North-West Highlands of Scotland. *Mem. Geol. Surv.*

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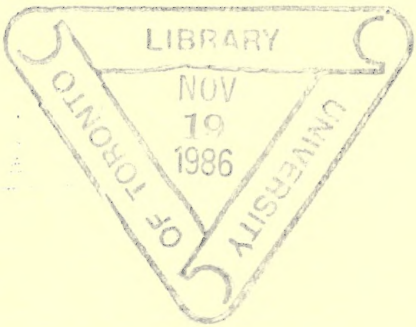
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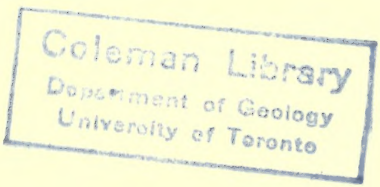
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